ical Report

# 1981 CCOPE PROBE MESONET
# Calibration and Maintenance Measures



Prepared for
U.S. Bureau of Reclamation

Under Cooperative Agreement 1-07-81-V0175

By

Montana Department of Natural Resources and Conservation

7-2090 (4-81)
Bureau of Reclamation

# TECHNICAL REPORT STANDARD TITLE PAGE

**1. REPORT NO.**

**2. GOVERNMENT ACCESSION NO.**

**3. RECIPIENT'S CATALOG NO.**

**4. TITLE AND SUBTITLE**
1981 CCOPE PROBE Mesonet Calibration and Maintenance Procedures

**5. REPORT DATE**
June 1983

**6. PERFORMING ORGANIZATION CODE**

**7. AUTHOR(S)**
Larry Holman and Jim McInerney

**8. PERFORMING ORGANIZATION REPORT NO.**

**9. PERFORMING ORGANIZATION NAME AND ADDRESS**
Montana Department of Natural Resources
and Conservation
Water Resources Division
32 S. Ewing, Helena, MT 59620

**10. WORK UNIT NO.**

**11. CONTRACT OR GRANT NO.**
1-07-81-V0175

**12. SPONSORING AGENCY NAME AND ADDRESS**
Bureau of Reclamation (USDI)
Office of Atmospheric Resources Division
P.O. Box 25007, DFC
Denver, CO 80225

**13. TYPE OF REPORT AND PERIOD COVERED**
Technical Report
1979-82

**14. SPONSORING AGENCY CODE**

**15. SUPPLEMENTARY NOTES**

**16. ABSTRACT**
Preparation and shut-down activities associated with the operation of the 1981 CCOPE PROBE Mesonetwork involved testing and calibrating instruments to assure a quality data set. Data quality control was sought during all phases of the 1981 CCOPE PROBE Mesonetwork operations for wind speed, wind direction, temperature, pressure tendency, relative humidity, and precipitation instruments and for the electronic interfacing and transmission equipment. Testing of equipment began in August 1979 and continued through June 1982. Because of the prototype nature of the PROBE stations, many of the calibration procedures and techniques had not been thoroughly tested for operations in Montana. Subsequently, our further calibration and maintenance measures were at times by trial and error. Calibration and maintenance exhibited reasonable consideration for the many constraints encountered. As a result, the data quality for each parameter was generally good. Overall station performances were considered acceptable.

**17. KEY WORDS AND DOCUMENT ANALYSIS**

*a. DESCRIPTORS--*
CCOPE, PROBE, mesonet, calibration, monitoring, quality control, barometric, pressure, temperature, relative humidity, electronics, interface, DCP, meteorological, pyranometer, precipitation

*b. IDENTIFIERS--*

*c. COSATI Field/Group* COWRR: SRIM:

**18. DISTRIBUTION STATEMENT**
*Available from the National Technical Information Service, Operations Division, 5285 Port Royal Road, Springfield, Virginia 22161.*

**19. SECURITY CLASS (THIS REPORT)**
UNCLASSIFIED

**20. SECURITY CLASS (THIS PAGE)**
UNCLASSIFIED

**21. NO. OF PAGES**

**22. PRICE**

# 1981 CCOPE PROBE MESONET

## Calibration and Maintenance Measures

by
Larry Holman
and
Jim McInerney

A Technical Report to the
U.S. Department of Interior
Bureau of Reclamation
Division of Atmospheric Resources Research

Prepared by the
Montana Department of Natural Resources and Conservation
32 S. Ewing
Helena, Montana 59620

Under
Contract Number 1-07-81-V0175

June 1983

ACKNOWLEDGMENTS

The authors gratefully acknowledge their associates who have shared in the many tribulations and frustrations confronted during PROBE instrument calibrations, operations and maintenance. Those individuals whose contribution has been immeasurable and who have served professionally in significant ways towards the preparation of this report include Al Bessol, Allan Bessol, Robert DeLange, Richard Dunning, Diane Donnelly, Marvin Krader, Denis Leidholt, Myra Munday and Sarah Norman.

The knowledgeable assistance provided by Tom Engle made a significant contribution to the success of calibration and maintenance. Without his untiring help and understanding, the PROBE stations would not have exhibited the quality of performance that resulted.

Several Bureau of Reclamation personnel who have provided information, guidance and assistance in meeting the needs of PROBE station operation include Arlin Super, Bill Harrison, Mike Collins, Fran Politte, Judy Bonds, and Doug Hale.

D.C. Howard and Dan Nelson assisted with the graphics, and Peggy Todd edited this report. Donna Elser deserves special praise for her gracious assistance in typing and organizing the first several drafts. A hearty "thank-you" must be extended to Cheryl Cordier, Melissa Otis and Julie Frickel for the final typing of this report.

## NOTICES

The mention of trade names in this document does not constitute endorsement of the products by the Montana Department of Natural Resources and Conservation or the USDI Bureau of Reclamation.

CONTENTS



TABLES

FIGURES

## I. PURPOSE OF ACTIVITIES

Confidence in a particular datum is directly related to the reliability of its source. Consequently, the quality of the measurement capability of the Portable Remote Observation of the Environment (PROBE) mesonet has received high priority. The calibration equipment and methodologies used, within the scope of available resources, resulted in confidence in the final data. Both preseason and postseason calibration testing of monitoring equipment has been conducted to assure data quality control. This report describes PROBE field instrument calibration activities associated with the 1981 Cooperative Convective Precipitation Experiment (CCOPE).

## II. GENERAL REMARKS

Preparation of PROBE instrumentation for the 1981 CCOPE field effort started with the 1980 mesonet operation. Operation of the 23 mesonet sites in 1980 served as a "shakedown" for the 1981 CCOPE mesonet procedures, and some of the 1980 calibration efforts served similarily for the 1981 CCOPE activities.

During the 1980 and 1981 PROBE site installations, elevations were estimated from USGS maps or calculated from the derivation of altitude from site barometric pressure, using nearby USGS survey stakes or bench marks as reference heights. The elevations were then used to calculate standard station pressure for each site. The standard station pressure was used to establish the calibration range for the pressure sensor.

Also during site installation, a measurement of true north was calculated and staked using a time-dependent theodolite survey of the sun's azimuth. This survey was subsequently used to orient the wind direction sensor and the transmitting antenna during instrument installation.

Another site installation exercise that served as a calibration function was the leveling of the platform structure assembly. This was necessary to assure proper vertical placement of both wind sensors and appropriate elevation angle alignment of the antenna.

Preseason lab calibration activities began during November 1980 with torque testing of wind sensors. During the following six months (Nov.-Apr.), other lab calibrations were completed for pressure, temperature, relative humidity, interface electronics (interface and signal conditioner unit/ISCU), and data collection platforms (DCP's). The personnel needed to prepare the instruments and associated equipment for approximately 100 PROBE platforms are listed in Table II.1. These personnel participated in calibration exercises, instrument assembly, prefield electronic repair and retrofitting, service material and supply inventory and preparation, field technique instruction, and data-handling software development.

Each PROBE platform was instrumented to monitor 6 or 7 meteorological parameters, which included: pressure, temperature, humidity, rainfall, wind speed and wind direction at all sites. Additionally, eleven platforms were

Table II.1

Personnel Required for PROBE Instrument Lab Calibration, Preparation and Shakedown

| Title | Function | Dedicated Time From Nov. - April |
|---|---|---|
| Field Manager | Administration | 5 months |
| Research Supervisor | Data handling mgmt. | 6 months |
| Field Supervisor | Equip. preparation mgmt. | 6 months |
| Electronics System Engineer | Electronics retrofit & calib. | 6 months |
| Electronic Technician | Electronics retrofit & Calib. | 6 months |
| Electronic Consultant | Electronics retrofit & calib. | 2 months |
| Electronic Consultant | Electronics retrofit & calib. | 2 months |
| Research Meteorologist | Data handling preparation | 6 months |
| Programmer Analyst | Data handling preparation | 6 months |
| Research Aides | Instrument calibration | 6 months |
| Research Aides | Instrument calibration | 6 months |
| Office Manager | Clerical management | 3 months |
| Statistical Clerk | Data entry and handling | 6 months |

Table II.2

CCOPE PROBE Equipment Calibration

| Equipment | Number Available to Calibrate | Period of Calibration |
|---|---|---|
| Wind speed | 107 | Nov. 80 - Jan. 81 |
| Wind direction | 107 | Nov. 80 - Jan. 81 |
| Temperature | 114 | Dec. 80 - Feb. 81 |
| Relative humidity | 114 | Dec. 80 - Mar. 81 |
| Pressure | 106 | Jan. 81 - Apr. 81 |
| Precipitation | 99+ | Apr. 81 |
| Electronics | 103 | Dec. 80 - Apr. 81 |
| Pyranometer | 11* | Prior to delivery to MLS |
| DCP's | 100** | Dec. 80 - Apr. 81 |
| Batteries | 112 | Nov. 80 - Apr. 81 |

\+ Raingages were calibrated during field installation.

* These were calibrated by Solar Energy Research Institute in Golden, Colorado, before delivery to Montana.

** Several DCP's exhibited problems that required exchange or shipment to the manufacturer. Therefore, at no one time were more than 100 DCP's functioning satisfactorily.

instrumented with a seventh sensor (a pyranometer) to measure diffuse and solar radiation. No local lab calibration was performed on the pyranometer or raingage prior to field installation. However, the daughter board/mother board electronics for the pyranometer and raingage received preseason calibration.

Preseason and postseason lab calibrations were performed for the remaining five parameters. The number of instruments calibrated for each respective parameter are listed in Table II.2. Some sensors were faulty and, therefore, could not be satisfactorily calibrated nor used for operations.

The incorporation of all calibrations to PROBE data files required development of an extensive prototype exercise to accomodate 96 reporting stations. The prototype software, necessary to retrieve, file and examine the PROBE data, had to be developed before field operations. Difficulties were compounded by the necessary conversion of software from the USBR CYBER computer in Denver to the local Perkin-Elmer minicomputer.

Nineteen major data handling routines (Table II.3), were prepared to manage PROBE data. The software incorporated calibrations for all parameters and also provided listings, plots and summaries of data. The major interface between the operations group and data management group before the field season involved establishing a calibration file from the calibration data. Because manufacturer design specifications indicated that linear relationships existed between sensor outputs and measured variables, the file that contained all of the sensor calibrations used only linear adjustments. However, the post season calibrations revealed that in most instances the relationship between the instrumented measurement of humidity and its respective sensor output was not linear.

The PROBE stations were powered down within 4 days after the CCOPE field season concluded. The postseason dismantling and removal of PROBE platforms and instrumentation began two weeks later. This delay allowed the Department staff to take a break from the intensive program exercises that had dominated their time for the previous nine months.

All stations' equipment and site facilities were removed and returned to storage at Miles City, Montana by 16 September 1981. Three to six personnel worked a total of about 850 hours dismantling and returning 96 PROBE stations to Miles City. After the stations had been removed, the instruments received postseason calibration checks. The following section describes the instrument calibrations that were conducted both before and after the CCOPE field work.

## III. CALIBRATION PROCEDURES AND EQUIPMENT

### A. Wind Speed

Description:

1. Sensor: Meteorological Research Inc. Wind Speed Sensor (model 1022S)

Table II.3

Computer Programs and Programing Aids Related to HIPLEX Mesonet Operations

| Program Name (Fortran Source) | Program Description |
|---|---|
| SFCANLF (TSOURCE) | Produces contoured plots of GOES platform data by objective analysis. GOES data file and calibration file must be on disk. |
| GAPF (TSOURCE) | Plots up to 72 hours of GOES platform data. All measured parameters are plotted on one plot. GOES data file and calibration file must be on disk. |
| GTMPF (TSOURCE) | Plots GOES platform data (parameter vs. time) for one or more platforms on the same plot. GOES data file and calibration file must be on disk. |
| LISTGF (TSOURCE) | Lists the actual data record, as transmitted from the GOES platform, for a given DCP ID and time. The GOES data file must be on disk. |
| MAPF (TSOURCE) | Plots on HB 7202A plotter or with PLOT10 FAA flight tracks, eastern Montana geography, and desired points to any desired scale. |
| MGTIMEF (TSOURCE) | Produces matrix listing for a CUT day showing the integrity of each hour's data record for each GOES platform in Montana. The GOES file must be on disk. |
| MNET1F (TSOURCE) | Lists all GOES platform data for a given project for a given time. |
| MNET2F (TSOURCE) | Lists all GOES data for a single platform for a given time interval. |
| LISTCF (TSOURCE) | Lists calibration data file, either for selected stations or the whole file. |
| SSPF (TSOURCE) | Determines standard station pressure, using the 45N summertime U.S. standard atmosphere, for a given altitude. |
| EFINPUT (TSOURCE) | Generates, on Tape 2, a file identical to the input file, except that all input records whose first ten characters are 'return' are converted to EOF's. |
| HRLYS (TSOURCE) | Lists data for a selected GOES platform on each hour for the selected time interval. |
| RADCOOR (TSOURCE) | Generates a file (on tape 2) of station IDS, LATS, LONS, X Radar Coordinate, and Y Radar Coordinate using a great circle routine from a file (on tape 1) containing 3-Char ID, LAT and LON in the format: XXX DDD MM SS DDD MM SS. |

TABLE II.3 (continued)

| | |
|---|---|
| SUMMRY (TCLIB) | Produces a listing of max, min, and means for temperature, pressure, etc. on a daily basis for a selected station and time period. |
| UNITEST (TCLIB) | Routine to produce statistics on mesonetwork data. Designed for use in determining "Analysis Calibrations" for individual platform sensors for case study analysis. |
| CF2PE (TSOURCE) | Will generate a permanent file (9CF2PE) listing the calibration data from a given project and year for a GOES platform calibration file. Written to provide output to use on the Perkin-Elmer. |
| GF2PE (TSOURCE) | Will generate a permanent file (9GF2PE) listing the raw GOES platform data for the desired project/year and time interval. Written to provide output to use on the Perkin-Elmer. |
| CLSTDMP (DNRCPRC) | A procedure file which generates and submits a job to dump (Backup) the entire ER1200I catlist on magnetic tape. |
| FITTABL (TWOURCE) | A routine which fits a 5th order polynomial to input data points (locally), and produces a table (on tape 13) of X vs. Y, DY/DX, and (D/DX)DY/DX. |

2. Design specifications:

    starting threshold ................0.22 m/s
    response distance .................1.5 m (63% recovery)
    flow coefficient ..................1.8 m/Rev.
    accuracy ..........................0.07 m/s or 1% of wind speed
    range .............................0.22 - 50 m/s
    output - voltage ..................pulses, approx. 4v peak-to-peak
    - frequency 0 to approx. 2500 Hz
    - impedance ................less than 10 k$\Omega$

3. Standard: Waters Manufacturing Inc. torque watch gauge (model 366-3)

Procedures and Discussion:

1. Preseason calibration: In December of 1980 DNRC personnel traveled to Boulder, Colorado to use National Center for Atmospheric Research (NCAR) facilities and equipment to calibrate pressure sensors and thermometers to NCAR standards. Both new and used wind speed sensors were tested in NCAR's wind tunnel, with the intention of establishng a starting-torque-to-starting-threshold relationship.

The new wind speed sensor, with a starting torque of less than 0.003 oz.-in., had a lower starting threshold than the wind tunnel standard. The used sensor with a torque of 0.007 to 0.009 oz.-in., had a starting threshold of 0.8/m/s. From this data, no clear relationship between torque and starting speed developed. The minimum torque measurable by the torque watch is 0.003 oz.-in. To be assured that the sensors had the lowest possible starting threshold it was decided that no sensor was field-ready unless its starting torque was less than 0.003 oz.-in.

All sensors' torques were recorded. Those sensors that required greater than a 0.003 oz.-in. torque to rotate the shaft were dismantled and their bearings were cleaned in an ultrasonic cleaner. If the sensor still failed this torque test, the bearings were replaced.

2. Postseason calibration check: All sensors were tested with the torque watch and the starting torques were recorded. Of the 100 sensors tested, 42% required a torque greater than 0.003 oz.-in. to start the shaft turning. Nine sensors had frozen bearings; the remainder had starting torques between 0.003 and 0.015 oz.-in. It should be noted that this latter starting torque value is not sufficient to stop the anemometer cups from turning, even in very light winds.

3. Discussion: Overall, the wind speed sensor performed satisfactorily during the field season. Because of the moderate dust environment of eastern Montana, bearing malfunction was expected, and did occur.

   A modification of the wind sensor to protect the bearings from liquid water was provided by the manufacturer midway through the field operations. Because of late delivery, along with significantly increased frictional torque of the conversion kit, it was decided not to mount the modification.

   The wind speed data collected during the field season is considered of good quality. There was no reason to suspect that the wind speed measurement variability was not consistent from station to station nor within station performance. Also there was no suggestion from the data record to dispute the manufactuer's claimed accuracy. The accuracy of the sensor was not tested; it was assumed to perform within specifications.

   Therefore, the measurements by the wind speed sensor were assumed to be an accurate assessment of the wind speed; exposure would affect the data more than instrument performance.

B. Wind Direction

Description:

1. Sensor: Meteorology Research Inc. Wind Direction Sensor (model 1022D).

2. Design specifications:

starting threshold ................0.31 m/s
delay distance ....................0.13 m (50% recovery)
damping ratio .....................0.4 at 10° angle of attack
accuracy ..........................± 1.5°
range .............................360°

3. Standard: Waters Manufacturing Inc., torque watch gauge (model 651X-3)

Procedures and Discussion:

1. Preseason calibration: All sensors were checked with the torque watch. If the starting torque was greater than .25 oz.-in. (the minimum measurable torque), the bearings were cleaned, and that sensor was tested again. The potentiometers of the sensors were checked for discontinuity.

2. Postseason calibration checks: All sensors were checked for starting torque. Eleven percent of the sensors had a starting torque greater than 0.25 oz.-in. However, examination of the daily data indicated that all sensors were functioning properly at season's end.

3. Discussion: The wind direction sensor performed very satisfactorily with only infrequent problems. Wind direction data were considered good to excellent. The major concern associated with wind direction measurement is misorientation, which should be less than ± 5°. As with wind speed, the station-to-station and within-station variability should be consistent and minimal. There was no reason to suspect the manufacturer's claimed accuracy. The accuracy of the instrument was satisfactorily tested in 1980 and subsequently assumed to perform within specifications. Several wind direction sensors were mounted on a 360° protractor grid. The measured angles were plotted against output voltage with no problems encountered.

   The wind direction measurements were assumed to be accurate; exposure considerations would probably affect the applicability of the data record more than the instrument performance or orientation.

C. Temperature

Description:

1. Sensor: Weathertronics Relative Humidity and Temperature Probe (model 5121)

2. Design specifications:

range .............................-30 to +50°
element type ......................thermistor
accuracy and interchangeability ...±0.15 °C
linearity deviation ...............±0.16 °C

sensitivity .......................0.0067966 Vin/$^{o}$C
output @ -30 $^{o}$C ..................+3.076840 VDC
output @ +50 $^{o}$C ..................+1.120464 VDC
load resistance ...................1 megohm
time constant .....................10 seconds

3. Standards:

   2 Fluke 8050A multimeters
   1 YSI 3-thermistor bridge
   3 (-38 to +2 $^{o}$C) Yel-Bak R.S.C.O. - Cenco Astm Thermometers
   6 (-8 to +32 $^{o}$C) Yel-Bak R.S.C.O. - Cenco Astm Thermometers
   1 (+25 to +55 $^{o}$C) Yel-Bak R.S.C.O. - Cenco Astm Thermometers
   1 Braun Thermonix (model 1460)

Procedures and Discussion

1. Preseason calibration: In December 1980 DNRC personnel used NCAR facilities and equipment in Boulder to calibrate the YSI Thermistor Bridge and the Yel-Bak R.S.C.O. - Cenco ASTM Thermometers to serve as standards for calibrations in Montana.

   A calibration chamber was constructed (Figure III.1), and was filled with a 50/50 water-antifreeze solution, to a level approximately two inches below the plate that held the tubes. All of the tubes had a 3/4" pipe coupling soldered at the top of the pipe to hold the tubes at the same level. A Braun Thermo mix was used to regulate temperature and mix the water-antifreeze solution.

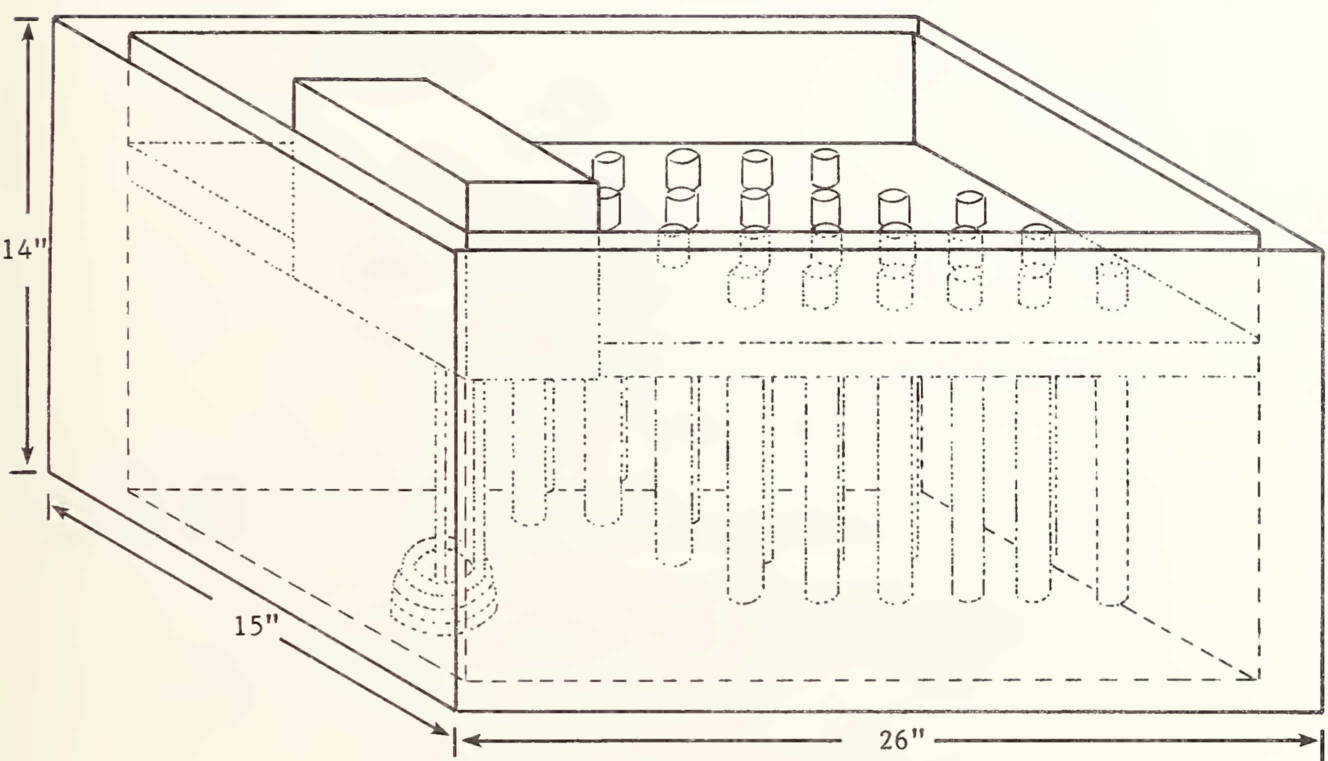
   As many as twenty-four temp/RH probes could be checked at one time. A probe was inserted into the tube until its sintered filter rested on the bottom of the tube. A rubber stopper was fitted around the probe wire and inserted in the top of the tube to restrict air flow.

   Temperature was monitored by a 3-thermistor bridge set inside one of the center tubes and by up to 3 thermometers (depending on temperature). The chamber was cooled to approximately -10 $^{o}$C and sensors were inserted into the tubes and allowed to stabilize. After stabilizing, the output voltage was monitored and recorded for each sensor. Also, the temperature of the chamber solution was routinely monitored during the calibration exercise.

   This procedure was repeated in approximately 10 $^{o}$C increments up to +50 $^{o}$C. From these data, a calibration line was established.

2. Postseason calibration check: The calibration chamber was filled with ice and water to a level approximately two inches below the plate that held the tubes. Sensors were inserted into the tubes and allowed to stabilize. Then the output voltages were recorded. The temperature of the water bath was then raised to approximately 50 $^{o}$C and the process was repeated. A line was fitted to these two points and then compared to the preseason calibration.

Figure III.1 "PROBE" Temperature Sensor Calibration Chamber



3. Discussion: The maximum deviation between the preseason and postseason calibration lines for all 101 sensors was .71 °C; the minimum was .07 °C and the average was .24 °C. From these data the temperature sensor performance was shown to be exceptional. Data are considered to be excellent quality. The station-to-station and within-station variability are minimal and consistent. The instrument performance was close to the manufacturer's claimed specifications.

D. Relative Humidity

Description:

1. Sensor: Weathertronics RH Temp Probe (model 5121).
2. Design specifications:

| | |
|---|---|
| sensing element................ | thin film capacitor |
| capacitance.................... | 45pf at 0% RH, 20 °C |
| sensitivity.................... | 0.1pf/%RH |
| range.......................... | 0-100%RH |
| response time.................. | 1 sec. for 90% of step change in RH |
| hystersis...................... | ±1% between 0-80%RH |
| linearity...................... | ±1% between 0-80%RH |
| supply voltage................. | 3.600 volts |
| output voltage................. | 0-100mV(0-100%RH) |
| load impedance................. | 1000 ohms |
| temperature coefficient........ | 0.05%RH/°C |

3. Preseason standards:

   2 Weathertronics relative humidity calibration chambers (model 5150) (Fig. III.2)
   4 Fluke multimeters (model 8050A)
   1 Hewlett-Packard model 6215A power supply
   1 Fluke temperature probe (model 80T150)

4. Postseason standards:

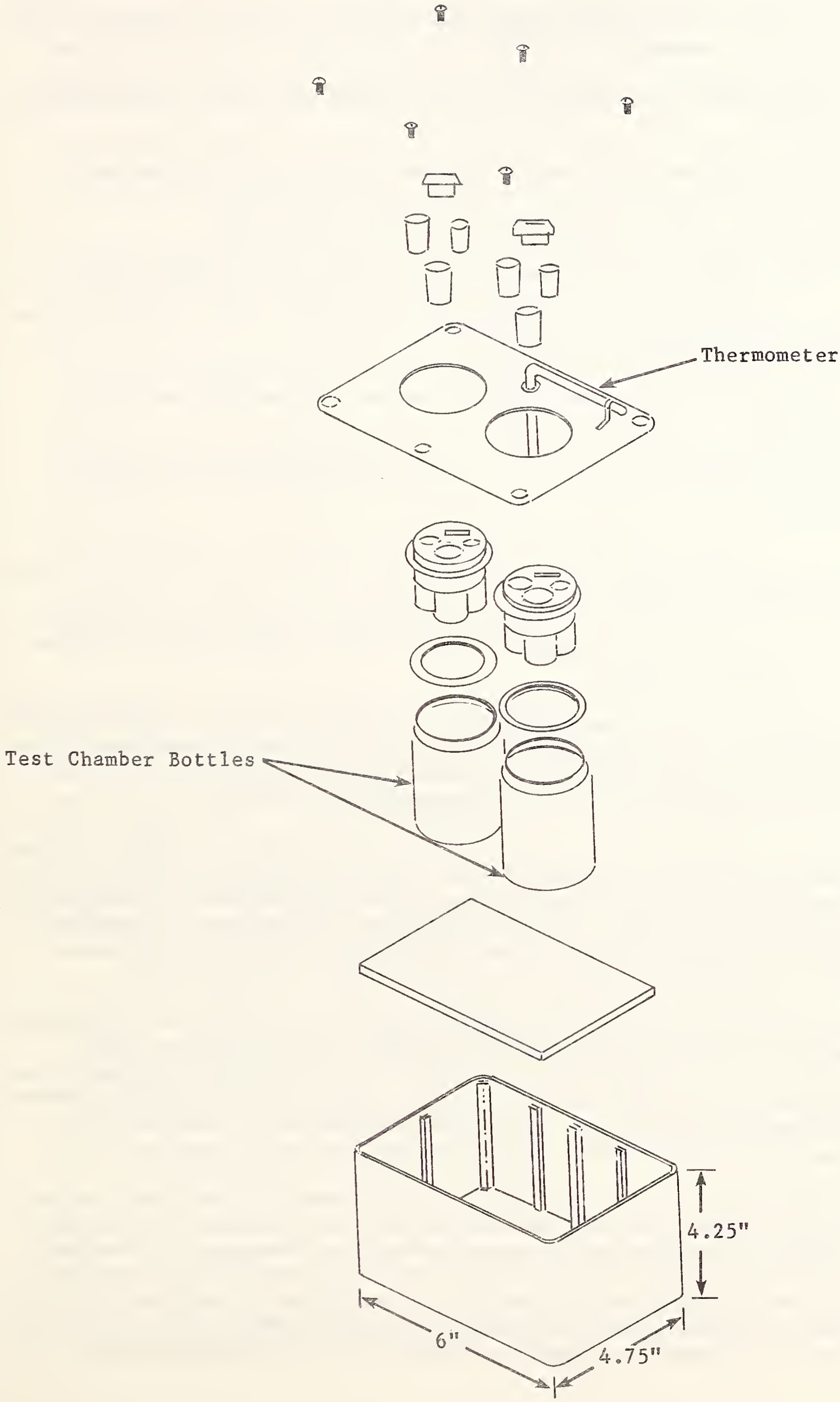
   1 Weathertronics psychrometer (model 5230)
   1 Setra pressure sensor (model 270)
   3 Fluke multimeters (model 8050A)

Procedures and Discussion:

1. Preseason calibration: Weathertronics recommends using a saturated salt solution, which establishes a known humidity within a test chamber, to calibrate the relative humidity of the model 5121 probe. Two test chambers were set up with a saturated lithium chloride-distilled water solution (RH-12%) and two other test chambers held a saturated sodium chloride-distilled water solution (RH-75%).

   Calibration chamber temperature was monitored by a thermometer situated between two test chambers, and air temperature was monitored

Figure III.2 Humidity Calibration Chamber



by the Fluke model 80T150 temperature probe, situated between the two calibration chambers.

In establishing a calibration for each sensor the following procedure was used.

a. Output voltage of the power supply was adjusted to 3.600 volts.

b. Sensor input leads were connected to the power supply.

c. A 1000 ohm load resistor was connected between the output leads.

d. Sensor output leads were connected to the multimeter, which monitored sensor output in millivolts.

e. The sensor was placed into a test chamber (either LiCl or NaCl solution).

f. Over 40 observations of sensor output and air temperature were recorded for a two-hour time period (to allow the test chamber to stabilize).

g. After the two-hour period the sensor was inserted into the other salt solution test chamber.

h. Sensor output and air temperature were again monitored and recorded for a two-hour period.

An exponential curve was fitted to each set of sensor output data and final sensor output values were estimated for the respective high and low humidities. From these estimated values of sensor output the sensor calibration was established using a linear fit.

2. In situ calibration: Soon after the field operational PROBE stations began reporting, it became evident that the preseason calibrations were not valid at high humidities. Humidity maximums as high as 175% were being calculated from the preseason calibration. All stations reported maximum humidities over 100%. The mean of the maximum relative humidities was 120%, with a range of 106% to 175%.

A new calibration was established using the preseason calibration low humidity data points and reported maximum humidities from each station. The humidity data indicated that the accuracy of the sensor increased with lower humidities, so it was assumed that the preseason calibration was the best estimation of humidity in the low range; therefore, the low range humidity data point was maintained.

Several days' (6-12) data were collected where the sensors reported high humidities for long periods of time (1-12 hours). The maximum humidities recorded on those days were then averaged. It was then assumed that this average maximum humidity actually corresponded to a real humidity between 94% and 100%. Corresponding maximum relative humidity observations from the Miles City FAA persisted in the 93-99% range. It should be noted that, according to the manufacturer

(Vaisala), the output of the sensing element would become nonlinear at humidities greater than 65% (Figure III.3). It was assumed that the upward drift occurred because the sensors were saturated and, therefore, reported a higher humidity than was actually present.

The average humidity was matched with an actual humidity of 103%, rather than a humidity between 94-100%, to obtain a better match to the slope of the linear portion of the sensor output (Figure III.4).

3. Postseason calibration check: Due to the obvious problems with the preseason calibration using the salt solution, the postseason calibration check compared sensor output with psychrometer wet-bulb-dry-bulb derived humidities. A calibration chamber was constructed of plywood and plexiglass. Four humidity ranges were established where sensor output was compared with humidities derived from psychrometer readings. All 101 sensors were placed within the chamber, which was then sealed with duct tape. Also inside the chamber was the psychrometer and a fan blade mounted on the end of an eight-inch shaft connected to a motor mounted externally (Figure III.5).

   The following procedure was used in checking each sensor:

a. To obtain a low humidity, two pans of oven-dried desiccant were placed inside the chamber. The chamber was then sealed and allowed to stabilize overnight. The next morning, with the fan circulating the chamber air, a humidity of 13.5% had established.

b. Sensor input leads and output leads were connected to the RH electronics interface card (RH daughter board) of the electronics interface board (mother board). The RH daughter board's supply voltage was adjusted to 3.600 volts and this supply voltage was monitored with a Fluke 8050A multimeter. The sensor output leads were also connected to a Fluke multimeter.

c. An individual sensor was moved around within the chamber in puppet fashion. Its readings consistently indicated that vertical and horizontal RH gradients were insignificant. This check was done before and after all sensors were read at each humidity.

d. For each established humidity range, sensors were individually connected to the same RH daughter board. Their output was recorded, as well as corresponding chamber wet bulb temperature, dry bulb temperature and pressure.

e. After completing the low humidity (~14%) check, the chamber was opened and the desiccant was replaced with warm water. The chamber was resealed and allowed to sit for 1 hour.

f. After the chamber humidity stabilized at 96%, the sensor output, the chamber temperature (wet- and dry-bulb), and pressure were again recorded for each sensor.

g. The water was removed and the chamber was allowed to dry overnight. The next morning when the chamber was sealed, a humidity of 80% had

Figure III.3 Drifting of Sensing Element as a Function of Humidity

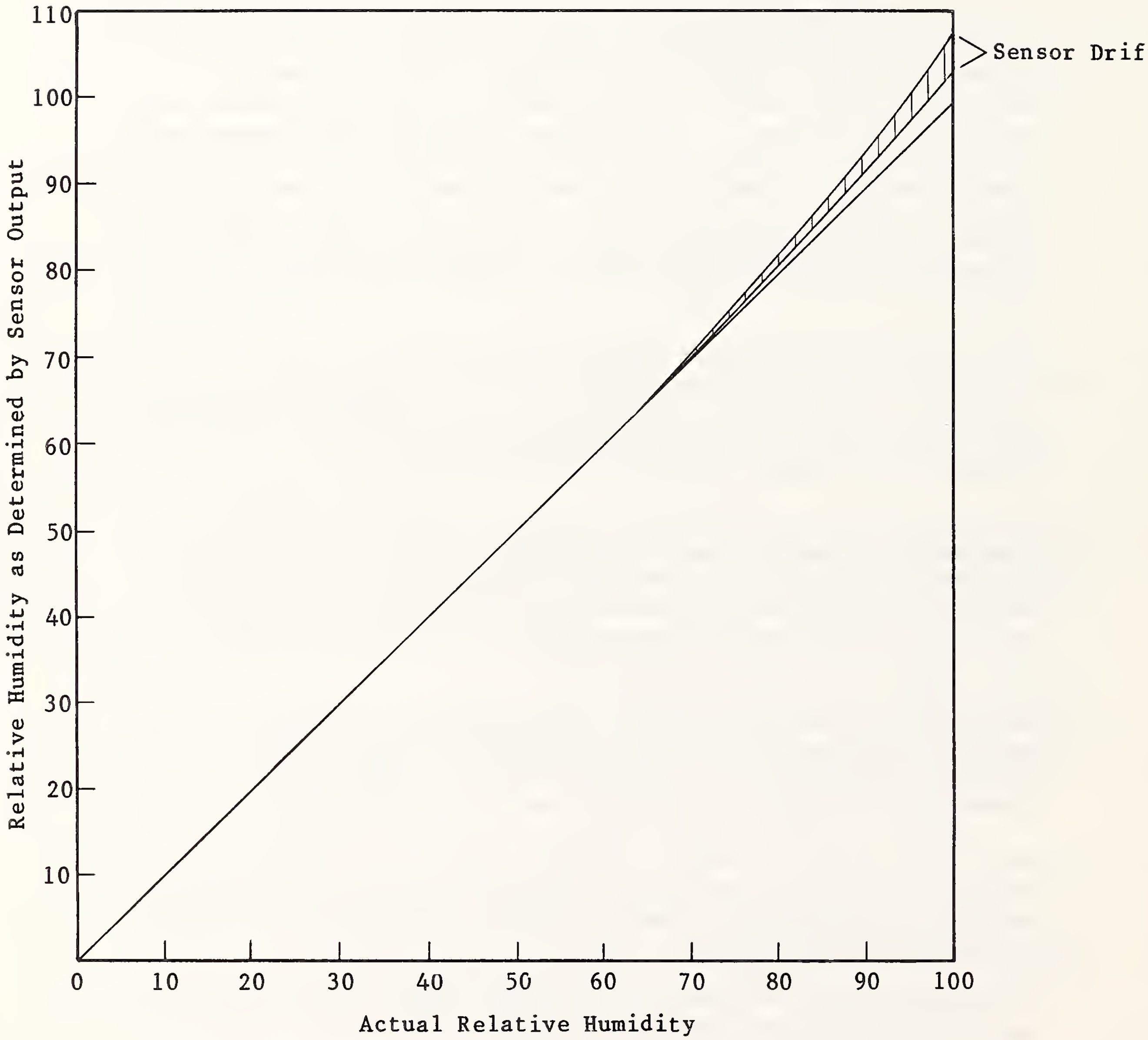


Figure III.4 "In SITU" Calibration Humidity Adjustment

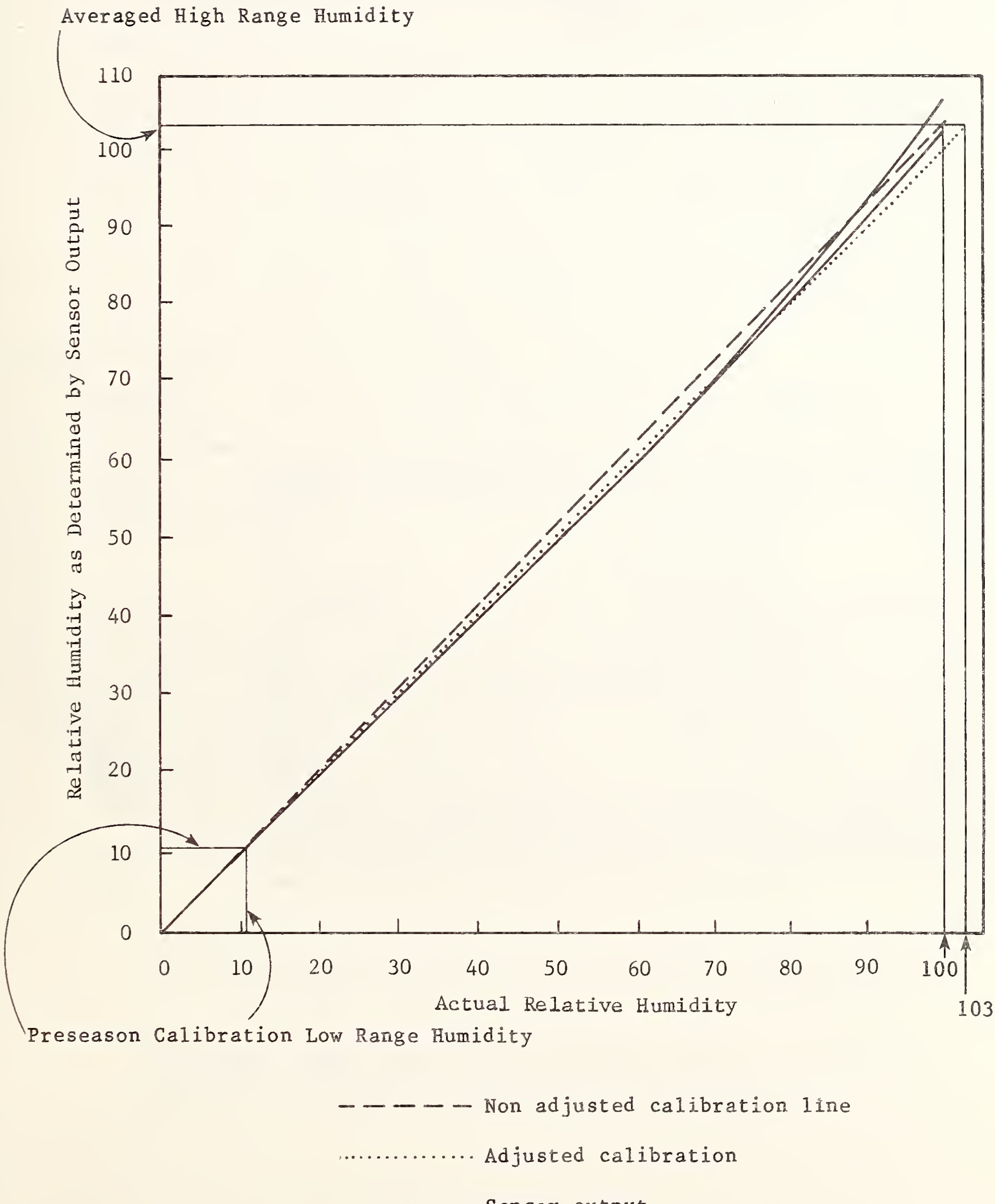
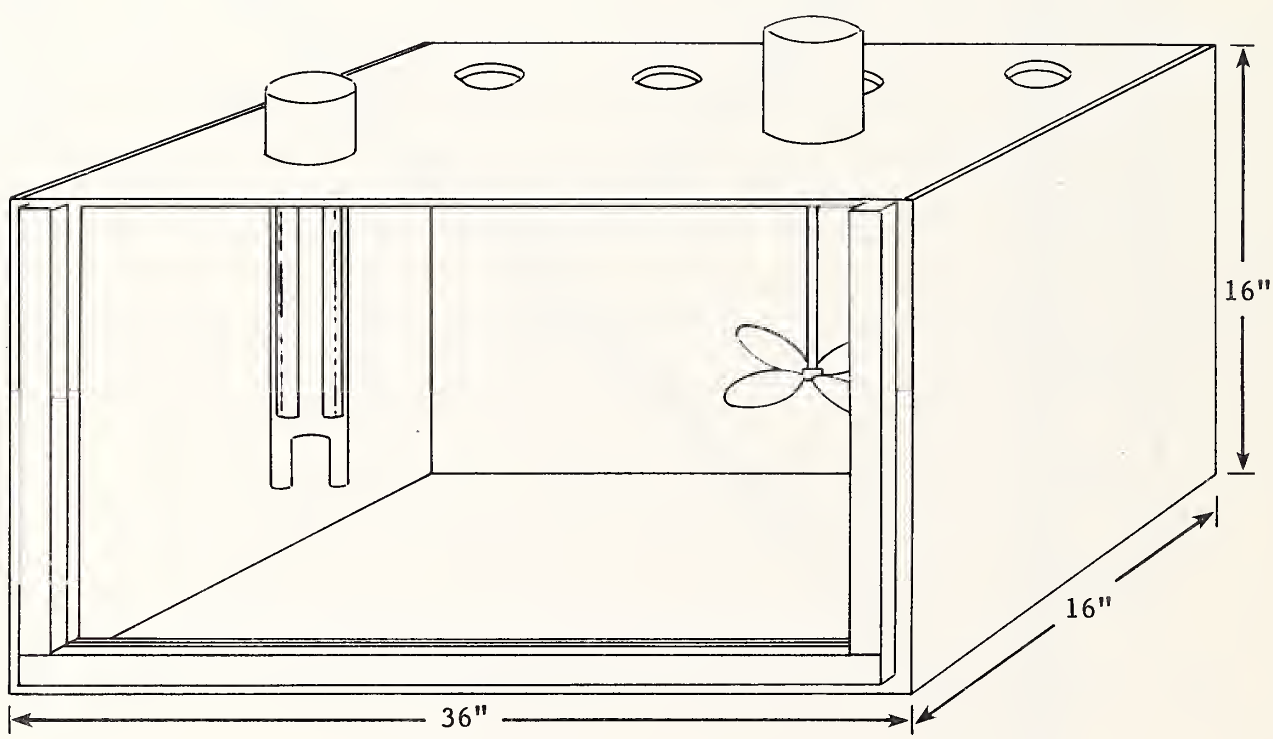


Figure III.5 "PROBE" Postseason Humidity Sensor Calibration Chamber



been established, and the readings were again recorded for each sensor. Moisture was apparently retained within the plywood walls of the box to hold the relative humidity at 80%.

h. The chamber was allowed to dry, with the aid of a heat gun and desiccant, until a humidity in the 40% range was established.

i. Readings were again recorded for each sensor.

4. Discussion: According to the manufacturer, the output from the relative humidity sensing element becomes nonlinear and will drift at humidities greater than 65%. This nonlinear drift was not considered during the calibration attempt but subsequent review suggests it may be an important consideration. The computer software developed to handle the PROBE mesonet only allowed for a linear fit to any calibration. The preseason and in situ calibrations were designed to try to match the slope and Y- intercept of the linear portion of the sensing element output. The saturated salt solutions ($LiCl-H_2O$ and $NaCl-H_2O$) were used in an effort to stay within the linear area of the sensor output.

Maintaining a stable calibration chamber temperature was the major problem encountered during the preseason calibration. Room temperature varied 3-5 $^{o}C$ with the cycling on and off of the room furnace. This created a smaller-scale oscillation of temperature within the test chambers of about 1.3 $^{o}C$. The oscillation of temperature plus the mixing of room humidity when sensors were added or removed disturbed the equilibrium of the solution.

Because of the oscillation of the chamber temperature, the saturated salt solutions never reached equilibrium within the two-hour calibration period. The oscillation of temperature seemed to fluctuate the chamber humidity from 7-10% of its value. Therefore, the low end humidity (~12%) was thought to be within a 10-14% relative humidity range, while the high end humidity (~75%) was thought to be within a 65-85% relative humidity range. Efforts were made to further insulate the calibration chamber but were not successful. Because of a deadline, the temperature problem was never completely resolved.

When the in situ calibration was completed, three assumptions were made.

The actual relative humidity in the field was 94-100% during the time the highest humidities were reported by the PROBE station.

The sensing element was in the nonlinear region of its output, and reported a higher humidity than actually present.

The adjustment of the higher calibration point to 103% humidity would produce the greatest accuracy from the linear portion of the sensor output.

These three assumptions appear, in most cases, to be correct. When compared to the postseason calibration check, the in situ calibration generally agrees. However, there are specific cases documented in Appendix A where there are large differences between the postseason check and the in situ calibration. Possible explanation for these differences include:

The assumptions made for the in situ calibration did not apply for that sensor.

An error was made in the calculation of the in situ calibration.

The sensor was jarred while being transported from the field, which affected the output.

The 3.600 supply voltage was significantly different between the in situ calibration and the calibration check.

The sensing element aged.

An error occurred in recording the data of the postseason calibration check.

An error occurred in the calculations for the postseason calibration check.

A combination of any of the above.

While some of these explanations are more plausible than others, there was no reasonable way to isolate an explanation for the differences.

The postseason calibration check was designed to make maximum use of limited personnel and time. The calibration chamber was designed to accommodate all of the sensors. Therefore, all the sensors could be checked in very nearly the same humidity environment. Because of chamber leaks, the humidity within the chamber drifted towards room humidity at the rate of between 2 and 4% per hour. Over 100 sensors would be checked within a 1 1/2-hour time span. The major portion of the time spent in performing a four-point calibration check was in establishing the humidity within the range wanted.

Errors associated with postseason calibration would most likely result from misreading the wet bulb temperature, dry bulb temperature and sensor output, or from improper logging of the observations.

During the postseason check it was discovered that some sensors were nonlinear over the entire humidity range tested. These sensors are also documented in Appendix A. Also included in Appendix A is Table A.1, which gives the in situ and postseason calibrations (slopes and intercepts) along with the corrections that can be applied to the in situ calibration humidities to obtain the postseason calibration humidities.

In the calibration of the relative humidity sensor, many factors must be considered in the selection of a calibration method and procedure. Some questions that must be answered before calibrations begin are:

To what environment (hot, cold, humid, dry, dusty, polluted) will the sensor be subjected ?

What time is available to complete the calibration (days, weeks, months)?

What personnel and type of equipment are available to perform the calibrations?

What is the humidity standard?

For local calibration exercises the laboratory environment affected the quality of the humidity sensor calibration. Equilibration and chamber humidity dilution were affected by the climate of the laboratory. Some suggested considerations to be addressed during calibration would include:

If the sensor is placed in a high humidity environment or in a cold environment that has periods of high humidity, it would be best to calibrate the sensor starting in a high humidity environment and going incrementally down. Likewise, if the sensor is to be placed in a hot, dry environment, the calibration should be performed in a low humidity environment and increment up. The minimum and maximum drift of the output of a near-saturated sensor must be determined in any calibration because it gives an indication of the deviation from linearity.

If salt solutions are used as the humidity standard, the calibration of the sensors requires considerably more time, since stable humidity must be achieved and maintained. Also, after the insertion of the sensor and the entrainment of room humidity into the chamber, it is necessary to wait until the test chamber has reached equilibrium before reading the sensor output.

Convenient adjustment of sensor output is possible with this calibration procedure because the sensing element is within the chamber, while the rest of the electronics are accessible for adjustment. It should be noted that adjustments should be made before a calibration starts. Once the calibration starts, no adjustment of the electronics should be made.

As opposed to repeatedly calibrating each sensor in confined individual chambers, the calibration exercise can be accelerated by placing several sensors in a much larger sealed chamber. Using an Assman psychrometer as the humidity standard, many sensors can be monitored within the same humidity environment, and calibration data recorded within a relatively short period of time.

Electronic adjustment of the sensor is not possible with this calibration method because the electronics are also confined to the interior of the chamber; therefore, output ranges could differ greatly from sensor to sensor over the humidity range tested. However, such scaling problems could be handled in the data management software. If potential inaccuracies occurred from this method of calibration, they would likely result from misreading the psychrometer or sensor output.

A preseason calibration and a postseason calibration check are recommended. The postseason calibration would serve as an indicator of sensor drift, aging, or as assurance that the preseason calibration is valid.

An in situ calibration method should also be performed after the sensors are installed in the field. To perform an in situ calibration, periods of stable, high humidity over the entire network should be selected from the data record and independently documented when the sensor output appears to maximize. The average of the highest values recorded for these periods would serve as one data point. Lower humidity data points are more difficult to establish in the field, but can be achieved by taking psychrometer observations at each site during low humidity periods.

The in situ calibration performed during the 1981 CCOPE field season provided a more reasonable estimate of relative humidity than the preseason calibration, because the sensors had an opportunity to equilibrate and perform without the errors and influence of a fabricated environment. The manufacturer's suggested calibration procedure required that the sensing element be inserted into a conditioned environment while the electronics were exposed to a dissimilar environmental climate. An in situ calibration eliminates this environmental stress associated with a lab calibration.

The in situ calibration provided humidity data that was reasonable and comparable to other data (e.g. local FAA surface observations). However, problems with this method of calibration might include:

Actual variations in RH from site to site during periods of high humidity.

Scarcity of extended periods (>4 hours) of high humidity over the entire network.

Once any calibration has been applied to the reported data, a routine check of that data should be conducted for signs of sensor aging, especially if it is in a dusty or polluted environment.

Unanswered questions concerning the limits and capabilities of the relative humidity sensor might include:

What are the maximum and minimum deviations in output of a saturated sensor?

How long does it take a sensor to become saturated? Unsaturated?

What is the difference in output when the sensor is subjected to a low-high-low humidity range over a short period of time?

These questions must be answered to understand the accuracy and resolution of the relative humidity sensor.

From the calibration exercises and checks that have been performed and applied on PROBE humidity sensors for 1981 CCOPE purposes, data records are believed accurate within ±7% RH in the 0-60% range for those sensors not referred to in Appendix A. For humidities greater than 60%, data are believed accurate to ±12% RH. For those sensors referred to in Appendix A, no reasonable assessment of humidity can be confidently assumed in the high humidity range.

The PROBE humidity data do not exhibit the desired resolution. It was unfortunate that a more reasonable and accurate humidity data set did not result, since the sensors proved to be sensitive, durable and convenient for field operational purposes. However, inadequately defined sensor performance characteristics and capabilities from the manufacturer along with operational inexperience with the humidity sensor contributed to the questionable quality of the data. As a result a better understanding of the sensor performance characteristics, as well as an environmentally controlled calibration routine for the sensor is highly recommended.

## E. Pressure

Description:

1. Sensor: Weathertronics Barometric Pressure Transducer (model 7115)

2. Design specifications:

| | |
|---|---|
| type | strain gage bridge and diaphragm |
| range | 700-1100 mb |
| excitation | 5-10 VDC; 20 V max. |
| output | nominal 20 mv @ 10 volt excitation/20 mb |
| accuracy | 0.1% deflections (includes linearity, hysteresis and repeatability) |
| thermal drift | 0.12%/°C uncorrected, 0.02%/°C corrected |
| temperature compensation | constant temperature recommended |

3. Standard:

Setra model 270 pressure transducer
Setra model 300C digital pressure indicator
Interface Signal Conditioner Unit (ISCU)
Fluke model 8050A digital multimeter
Hewlett-Packard model 5315A frequency counter

Procedures and Discussion:

1. Introduction: The PROBE mesonet platform was equipped with a Weathertronics (model 7115) pressure transducer. This unit was designed with the intended capability of sensing one tenth of one percent (.2mb) pressure tendencies over a 200-millibar range when excited with a 10 volt input. The available operating range for the Weathertronics pressure transducer was from 700-1000 millibars.

   For PROBE mesonet purposes each transducer was calibrated over an 80-mb range with the Standard Station Pressure (SSP) centered at midrange. The SSP is the mean pressure at the station elevation referred to as mean sea level pressure of 1013.25 mb, where the derived pressure was calculated from the 1966 U.S. Standard Atmosphere at 45° N latitude for July. Therefore, if a particular PROBE site had a SSP of 925 mb, the calibrated operating range of the transducer was configured to be from 885 mb to 965 mb.

2. Preseason calibration: Preseason calibration exercises included plumbing the Weathertronics transducer to a precision calibration standard (Setra model 270) in line with a water-filled manometer and control valve to increment the pressure at several calibration levels (Fig. III.6). Before the Weathertronics transducer was calibrated, it was heated and maintained at a constant temperature within an insulated styrofoam cartridge (not shown in Fig. III.6). This same insulated cartridge and heater element was installed at all field locations to maintain an approximately constant temperature environment for the transducer.

   All pressure transducers were calibrated under laboratory conditions prior to field installation. For calibration purposes, a transducer was linked to a power supply through the PROBE ISCU's (daughter board/mother board). Once mated and calibrated through the respective pressure daughter board, the respective components, including the pressure sensor, ISCU and heater cartridge, became a calibrated unit that was not to be separated or electronically adjusted under any circumstances after the calibration exercise.

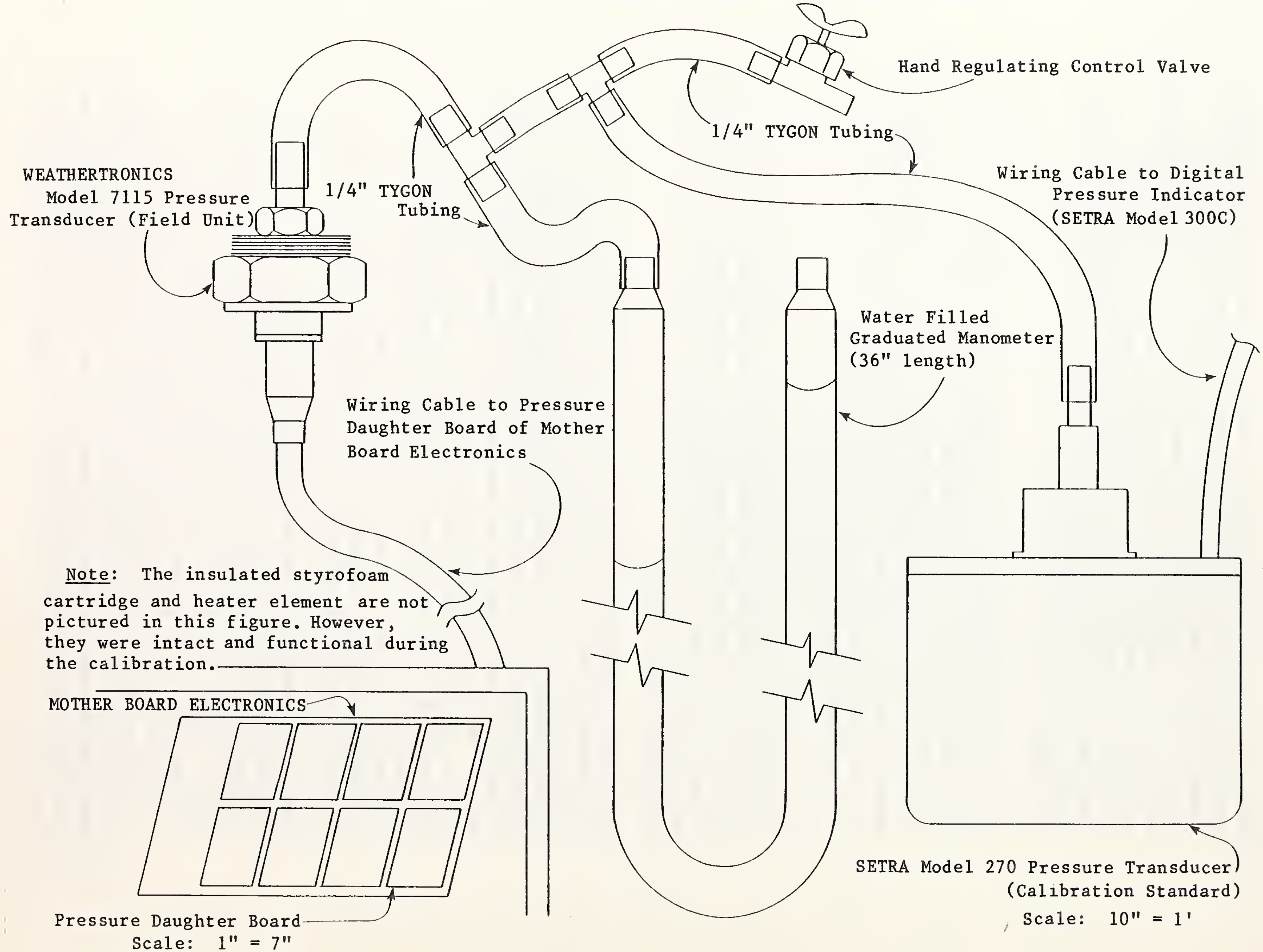
   The calibration exercise required a constant 10.0 volt excitation to the pressure transducer. This voltage input was obtained from an adjustable voltage source from the pressure daughter board which was one of eight potential daughter circuit boards that made up the ISCU mother board assembly. For calibration the output from the transducer was converted into a frequency ranging from 3-6987 Hz (corresponding to an 80 millibar range).

   The chamber calibration pressure was established within the airtight calibration assembly by blowing air into or sucking air from the Tygon tubing system. Once a calibration pressure was established, the piping assembly was sealed by fixing the regulating control valve to a closed position. The low point of the frequency range (3 Hz) was adjusted on the pressure daughter board to correspond to the SSP less 40 mb. The next range setting was 6987 Hz corresponding to the SSP plus 40 mb. After the minimum and maximum range points were respectively set on the pressure daughter board, then the chamber pressure was reset to the low range valve (SSP -40 mb) and the calibration frequencies were recorded for seven pressure levels including, in order: SSP - 40, SSP - 20, SSP - 10, SSP, SSP + 10, SSP, + 20, and SSP + 40 mb.

   The Setra model 270 pressure transducer served as a standard for all Weathertronics (model 7115) transducer calibrations. Three Setra pressure sensors (SN 31821, SN 30214, and SN 30213) were calibrated against NCAR standards at NCAR facilities in Boulder, Colorado, during December 1980. These Setra transducers then served as local standards for calibration exercises in the lab in Miles City, Montana.

   The Setra (model 270) transducer's design specifications included the capability to measure absolute barometric pressure within $\pm$.3 mb from 800-1100 mb operating range. More importantly, the hysteresis and nonrepeatability associated with the Setra was intended to be less than .01% of full scale ($<$ .1 mb). In addition, research into

Figure III.6 Preseason and Postseason Pressure Calibration Procedure



previous Setra transducer applications indicated that its performance and reliability record was very satisfactory and that it was durable and convenient to use.

A Setra model 300C digital pressure indicator and a Fluke 8050A multimeter were used with the Setra transducer to provide instantaneous readout of pressure in the chamber tubing.

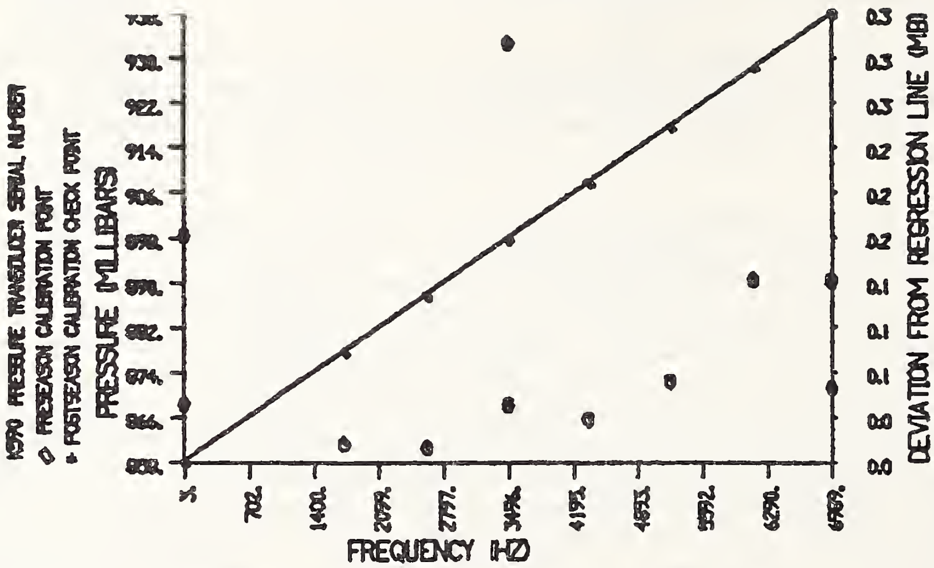
3. Field preparation and operations: On March 1, 1981, inventory records showed that 106 pressure transducers were available for calibration and subsequent field installation; however, because of functional inconsistencies or performance failures, many transducers did not calibrate satisfactorily. The specific problems occurring within the transducers were not investigated by the field technical staff since the equipment was under warranty for the most part, and adequate repair facilities or schematics were not available. Fifty-four transducers were returned to the supplier only after they repeatedly failed to perform satisfactorily. The supplier found that the sensors required a 5 volt excitation instead of 10 volts. The sensors were modified to accommodate a 10 volt excitation, retested and returned to Miles City.

4. Postseason checking: As time permitted and after PROBE platforms had been dismantled and returned to project headquarters in Miles City, a postseason check of the pressure calibrations was randomly conducted on 41 of the transducers. This included powering up the ISCU along with the heated pressure transducer (Figure III.6) and recording the corresponding Setra pressure reading for the respective ambient, low (3 Hz) and high (6987 Hz) frequencies. For example, a frequency output was initially recorded for the respective ambient pressure conditions. The chamber pressure was then reduced appropriately to a corresponding frequency output of 3 Hz and the respective pressure was recorded. Similarly, the chamber system was pressurized to correspond if the initial ambient pressure was not near the SSP for the respective transducer being checked, a frequency of 3490 Hz was conditioned and the corresponding pressure level was recorded.

5. Discussion: For the 41 postseason calibration checks, plotted points were compared with the preseason linear regression lines as shown in Figure III.7. The preseason calibration points and deviations from the preseason linear regression line for all points were also plotted and tabled as shown in Table III.1. The preseason regression equations for the 41 transducers checked after the field season are listed in Table III.2.

An examination of the original plots revealed several incorrect data values and possible bad calibration points. Improperly coded data were corrected and five sets of calibration points that were thought to be improperly recorded were moved from the calibration data set. Even after the data were corrected and calibrations replotted, only six transducers consistently exhibited postseason calibration

Figure III.7 K590 Pressure vs. Frequency




CIRCLED (O) POINTS REFER TO "DEVIATIONS FROM REGRESSION LINE".

Table III.1 K590 Pressure vs. Frequency Data

THE DATA SUMMARY BELOW IS FOR TRANSDUCER
(SERIAL NUMBER) K590

| CALIBRATION PRESSURE LEVEL (MILLIBARS) | CORRESPONDING FREQUENCY CALIBRATION (HZ) | DEVIATION FROM PRESEASON LINEAR REGRESSION CALIB. (MILLIBARS) | TIME OF CALIBRATION (PRESEASON OR POSTSEASON) |
|---|---|---|---|
| 858.43 | 3.2 | 0.04 | PRESEASON |
| 878.13 | 1734.0 | 0.02 | PRESEASON |
| 888.28 | 2623.0 | 0.01 | PRESEASON |
| 898.20 | 3495.0 | 0.04 | PRESEASON |
| 908.15 | 4360.0 | 0.03 | PRESEASON |
| 918.17 | 5245.0 | 0.06 | PRESEASON |
| 938.18 | 6989.0 | 0.05 | PRESEASON |
| 858.23 | 3.0 | 0.16 | POSTSEASON |
| 897.90 | 3490.0 | 0.29 | POSTSEASON |
| 928.29 | 6138.0 | 0.13 | POSTSEASON |
| 937.98 | 6987.0 | 0.12 | POSTSEASON |

Table III.2  Preseason Linear Regression Equations for Pressure Calibrations

For equation: Y = aX + b
Y is pressure in millibars (mb)
X is corresponding frequency in Hertz (HZ)
a is slope of regression line
b is pressure for theoretical frequency of 0 Hertz

| SENSOR SERIAL NUMBER | PRESSURE CALIBRATION STANDARD | NUMBER OF CALIBRATION POINTS | (a) SLOPE FOR REGRESSION LINE | (b) INTERCEPT ON "X" AXIS |
|---|---|---|---|---|
| 1A639 | 30213 | 7 | 0.011447 | 865.28 |
| 1A540 | 30214 | 7 | 0.011420 | 866.64 |
| J895 | 30213 | 7 | 0.011415 | 862.10 |
| J897 | 30213 | 7 | 0.011461 | 875.48 |
| J900 | 30214 | 7 | 0.011423 | 860.79 |
| J904 | 30214 | 7 | 0.011407 | 881.10 |
| J938 | 30214 | 7 | 0.011435 | 874.17 |
| K590 | 30214 | 7 | 0.011415 | 858.35 |
| K598 | 30214 | 7 | 0.011419 | 870.27 |
| K600 | 30214 | 7 | 0.011429 | 863.32 |
| K603 | 30214 | 7 | 0.011408 | 846.51 |
| K604 | 30214 | 7 | 0.011430 | 853.07 |
| K606 | 30214 | 7 | 0.011432 | 881.75 |
| K607 | 30214 | 7 | 0.011476 | 873.35 |
| K917 | 30213 | 7 | 0.011464 | 883.73 |
| K920 | 30213 | 7 | 0.011526 | 887.13 |
| K926 | 30213 | 7 | 0.012053 | 861.20 |
| K932 | 30213 | 7 | 0.011478 | 874.77 |
| L702 | 30214 | 7 | 0.011410 | 876.65 |
| L715 | 30213 | 7 | 0.011491 | 866.77 |
| L767 | 30214 | 7 | 0.011446 | 876.42 |
| M899 | 30214 | 7 | 0.011439 | 870.87 |
| M930 | 30213 | 7 | 0.011466 | 871.05 |
| X591 | 30214 | 7 | 0.011468 | 868.52 |
| X592 | 30213 | 7 | 0.011468 | 875.70 |
| X598 | 30214 | 7 | 0.011416 | 880.34 |
| X599 | 30214 | 7 | 0.011473 | 871.67 |
| X601 | 30214 | 7 | 0.011441 | 877.69 |
| X604 | 30214 | 7 | 0.011412 | 883.13 |
| Y019 | 30214 | 7 | 0.011436 | 873.85 |
| Y021 | 30214 | 7 | 0.011422 | 867.46 |
| Y025 | 30214 | 7 | 0.011419 | 870.59 |
| Y032 | 30214 | 7 | 0.011418 | 883.66 |
| Y769 | 30214 | 7 | 0.011412 | 884.57 |
| Y770 | 30214 | 7 | 0.011310 | 857.85 |
| Y772 | 30214 | 7 | 0.011421 | 880.41 |
| Z011 | 30214 | 7 | 0.011420 | 863.52 |
| Z013 | 30214 | 7 | 0.011421 | 867.33 |
| Z016 | 30214 | 7 | 0.011434 | 879.67 |
| Z020 | 30214 | 7 | 0.011425 | 885.20 |
| Z029 | 30214 | 7 | 0.011410 | 877.74 |

Figure III.8  J904 Pressure vs. Frequency

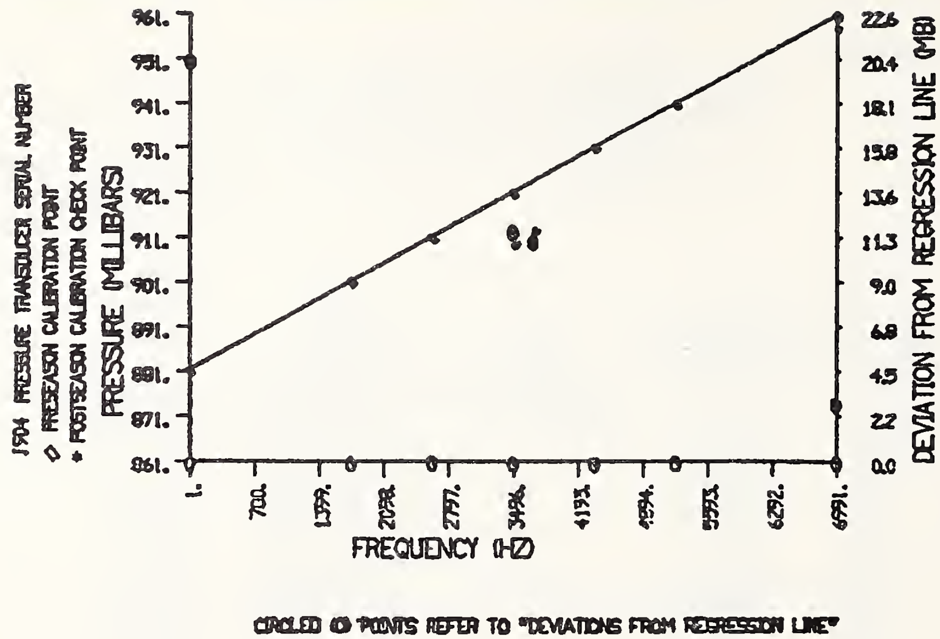



Figure III.9  K932 Pressure vs. Frequency

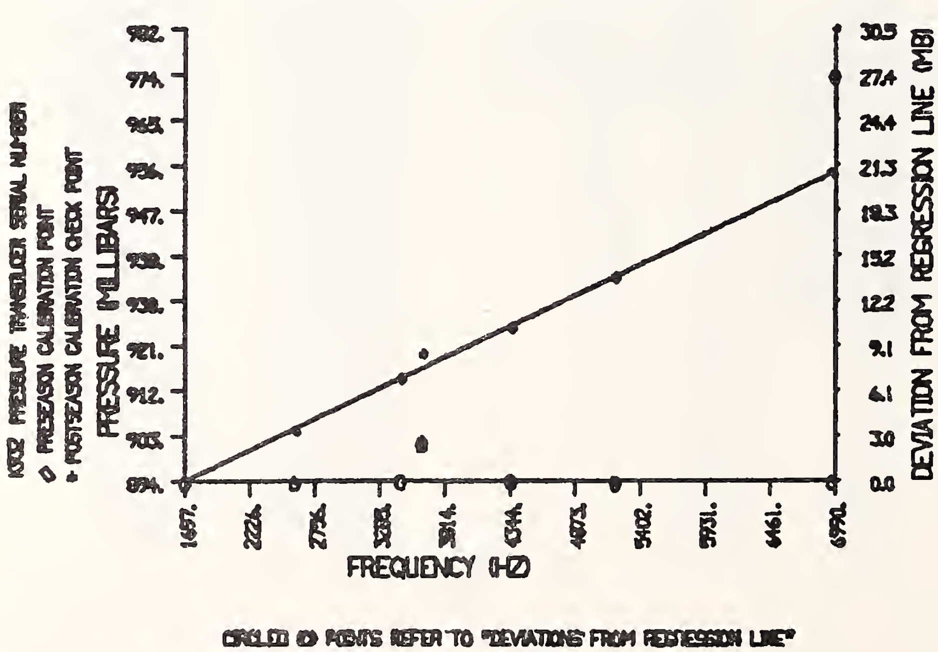
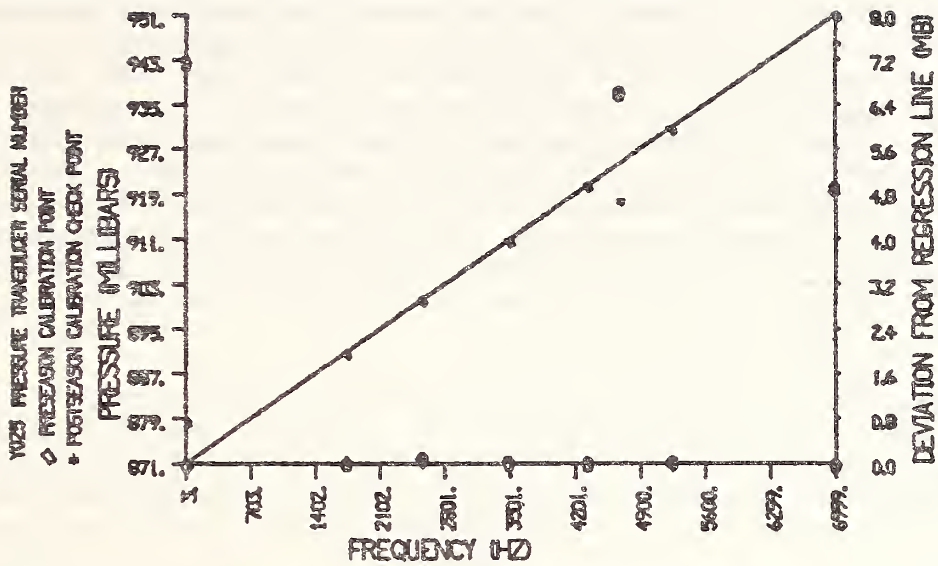
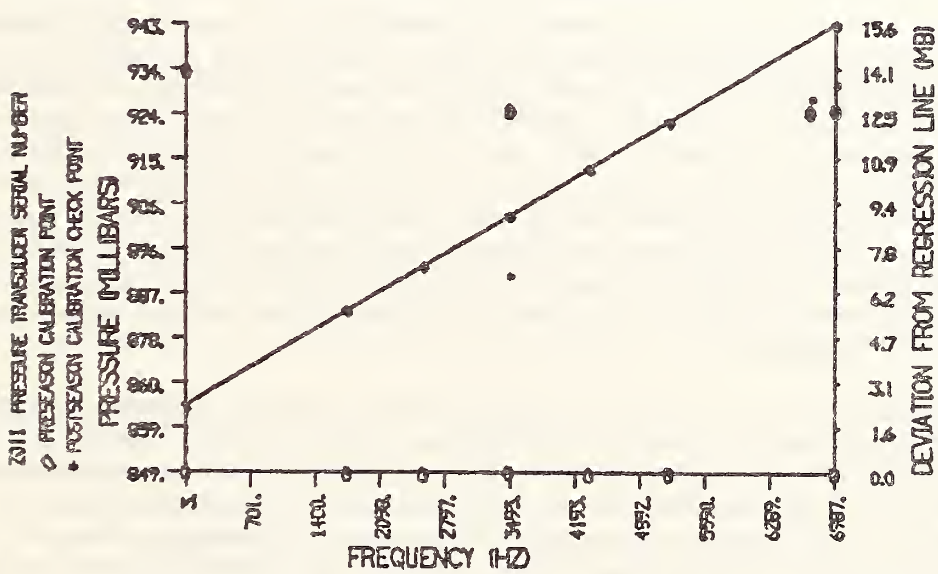


Figure III.10  Y025 Pressure vs. Frequency




CIRCLED (◇) POINTS REFER TO "DEVIATIONS FROM REGRESSION LINE"

Figure III.11  Z011 Pressure vs. Frequency




CIRCLED (◇) POINTS REFER TO "DEVIATIONS FROM REGRESSION LINE"

deviations within .5 mb of the preseason pressure curve. However, the relative slopes of preseason and postseason calibration lines were basically paralled in all but two cases. The differences between the preseason and postseason calibrations for transducers J904 and K932 as shown in Figures III.8 and III.9 were substantially inconsistent from one end of the calibration spectrun to the other (respectively 3-20 mb and 3-28 mb deviations from preseason linear regression). Uniformity in the relative measurement capability is evident; only 4 of 41 transducers deviated by more than .72 mb from an offset regression line parallel to the preseason linear regression line. Two others deviated 2.28 mb and 1.44 mb from an offset preseason regression line. See Figs. III.10 and III.11.

It is difficult to isolate the factors that may have caused deviations. The ISCU potentiometers may possibly have been jarred during transport or inadvertently adjusted during field operations; this may have altered the calibration. However, a review of field service log notes shows no in-field adjustment of either transducer.

For those many situations where the postseason calibrations are relatively parallel to the preseason calibration but vary considerably in absolute measurement, aging of the transducer diaphragm or environmental or operational stress on the components of the transducer may have created a shift of the absolute pressure-measuring capability. However, the ability to sense fluctuations in pressure in a consistent and accurate manner appears to have been preserved throughout the season for 39 of 41 transducers tested.

From the comparison of preseason calibration and postseason pressure checks, absolute pressure data at times exhibited within-station variations greater than 20 mb. Differences in adjacent station-to-station absolute pressure, which were reduced to sea level and averaged over a 6-hour period, were also observed in excess of 20 mb. Greater unaveraged absolute pressure differences from a 5-minute scan would likely occur between adjacent stations if a search of the data was conducted. Such station-to-station discrepancies certainly suggest that the absolute measurement of pressure might include errors in excess of 20 mb and, therefore, should not be relied upon as a confident assessment.

The derived change in pressure (relative pressure) showed reliable measurement from station-to-station as well as within-station. The relative pressure measurement could be relied upon for periods of one to several hours as long as no major temperature fluctuations occurred. With sudden and extreme temperature changes, the electronics interfacing exhibited unstable operating tendencies and reflected temperature dependent errors in the relative pressure record. However, examination of relative pressure differences on the order of .2 mb over 15-minute periods looked reasonable and compared favorably with other mesoscale features at stable operating temperatures.

Without additional analysis of the pressure data collected during PROBE exercises, it would be difficult to further verify the design

specification of $<.1\%$ error in pressure deflection accuracy. Generally the Weathertronics transducer maintained its relative pressure sensing calibration during PROBE operations.

It was apparent that the relative pressure resolution was more reliable than absolute pressure resolution. For the purposes of meso-scale studies in Montana, the Weathertronics pressure transducer provided an acceptable record of short term relative pressure fluctuations. However, the absolute pressure data record would often include errors on the order of $\pm 20$ mb.

F. Precipitation

Description:

1. Sensor: Belfort Cat. No. 5915RX-300MM
2. Design specifications:

accuracy........................1/2 of 1% F.S.
temperature range...............-40 to +50 °C
sensitivity.....................0.25 mm
range...........................0-300 mm
collector diameter..............203.2 mm

3. Standard: Belfort 300 mm calibration weight set.

Procedure and Discussion:

1. In-field calibration: Once the platform was erected in the field and all sensors were connected to the electronics interface board, raingage calibration data were established. The Handar 526A programming set was connected to the DCP to monitor the channel with the raingage output.

   The output for the weight of the raingage bucket was recorded. Twelve calibration (25 mm) weights were added to the bucket, one at a time. After each addition, the output was recorded. After all 12 weights had been placed in the bucket, the procedure was reversed and output was recorded after each weight was removed.

2. Postseason: During the summer of 1980, a network of 23 stations was operated. A calibration was established when the platform was erected and checked when the platform was shut down after the field season. The final season check included placing twelve raingage weights (25 mm) into the raingage bucket and recording the output from the Handar 526A programming set. No apparent sensor drift was detected from the raingage calibration. For this reason and because of manpower and time considerations, no postseason calibration checks were done on the raingages in 1981. It was assumed the calibration established during CCOPE installation was valid for the entire CCOPE period of operations.

3. Discussion: From the in-field calibration of the raingage, repeatable calibration exercises varied by as much as 4.5% from one calibration

check to the next during the day of installation. This variation represented a resolution of approximately ± 1.15 mm (~ ± .05 inch).

Had sufficient time and resources been available, the mechanical apparatus on the raingage should have been calibrated and serviced before field installation. With such preparation, the raingage might have provided repeatable calibration checks within 3% of each other. However, scheduled commitments did not allow for extensive raingage calibrations and service.

It should be noted that the minimum resolution that can be obtained from the variable potentiometer on the Belfort raingage is ± 0.4 mm. Therefore, to measure precipitation at a resolution less than ± 0.4 mm would require modification to the raingage.

G. Data Retrieval, Storage and Transmission:

Description:

1. Sensor Signal Storage: Electronics Techniques Inc., Interface and Signal Conditioner Unit (ISCU)

The ISCU is a modular design with a mother board and seven individual daughter sensor signal conditioner cards for wind speed, U-component, V-component, temperature, relative humidity, pressure and precipitation. The mother board can hold eight signal conditioner cards.

The ISCU provides operating and regulating voltage for sensors and signal conditioners and provides true digital averaging of certain sensed parameters.

2. Data Retrieval and Transmission: Handar model 524A Data Collection Platform (DCP)

frequency - 401.700996-401.847905 MHz (NESS ch 1-266)
RF power output - +40 dBm (10 Watts ±1dB)
timing sequence: transmission interval - 5 min to 63 hours 59 min.
synoptic delay interval - 5 min to 63 hours 59 min.
data storage - 1664 bits - scan readings - 104
data collection scan interval - 5 min. to 63 hours 59 min.
data collection scan delay - 5 min. to 63 hours 59 min.
analog input - 8 channels
digital input - 4 channels
DC power input - 12.5v ± 1.5v
operating temperature - -40 to +50 °C

3. Standards:
multifunction test set (MFTS) - ETI model
digital voltmeter (DCM) - Fluke model 8050A

frequency counter - Hewlett-Packard model 5315A
oscilloscope - dual channel
manometer
pressure measurement system - Setra model 270
wattmeter - Bird Thruline model 43
coaxial resistor - Bird Thermaline model 816A
programming set - Handar model 526A

Procedure and Discussion:

1. Preseason calibration: All ISCU's and DCP's were assigned to a field site and then electronically calibrated according to the procedures respectively documented in Appendices B and C. After calibration, the electronics were subjected to a 24-72 hour "burn-in" period. This period included supplying the daughter boards with input voltages that simulated mid-range output for respective sensors. The pressure sensors were the only ones connected to the ISCU's during the burn-in period. The DCP's were programmed and the data were transmitted through the satellite. After an ISCU/DCP unit continuously transmitted correct data, it was determined to be ready for field installation.

2. Postseason calibration check: Between August 6 and 10, 1981, eighty-three PROBE mesonet stations were powered down for the season. Thirty-two of the stations had an in-field calibration check performed on the ISCU's during this power-down.

   Between September 14 and October 14, 1981, postseason lab calibration checks were performed on 42 ISCU's which had been committed to other projects. Some of the ISCU's checked in the electronics lab were ones that also had in-field checks.

   The majority of the postseason calibration checks of the ISCU's were performed by Bureau of Reclamation (USBR) personnel.

   The pressure daughter board and sensor were checked as a unit for only 42 stations that were sent to other projects. The results of the pressure calibrations are discussed in Section E. The remaining 41 operational ISCU's had calibration checks performed on them between October 14, 1981 and January 31, 1982. Table III.3 shows the percentages of the respective daughter boards that maintained their calibration.

   There were no postseason checks performed on DCP's. Seventy-four DCP's were sent to other projects soon after they were brought in from the field. Time constraints restricted checking the remaining DCP's.

3. Discussion: As shown in Table III.3, great care must be taken in the transport of the ISCU's to and from the field. Despite a diligent effort to lab-seal all variable potentiometers before field installation and not adjusting the electronic components during field service, the ISCU's did not retain their calibrations as desired. The reasons an electronics board would not maintain calibration might include: (1) temperature or humidity variations (different from

Table III.3 Daughter Boards within Calibration Limits

those at the time of lab calibration), (2) differences in supply voltage, or (3) jarring of the board. The only way one of these factors can be reasonably reduced was to take extreme care during the transport of the electronics board. Since no DCP's were checked during the postseason, it was not known whether they held their calibration.

| Endseason in-field calibration check 6-10 August 1981 (32 ISCUs) | | | | | |
|---|---|---|---|---|---|
| Wind Speed Board | U-component Board | V-component Board | Temperature Board | Relative Humidity Board | Precipitation Board |
| 53% | 47% | 63% | 13% | 3% | 38% |
| Postseason calibration check (lab) 14 September - 14 October 1981 (42 ISCUs) | | | | | |
| Wind Speed Board | U-component Board | V-component Board | Temperature Board | Relative Humidity Board | Precipitation Board |
| 15% | 12% | 22% | 20% | 0% | 10% |
| Endseason calibration check (lab) 14 October 1981 - 30 January 1982 (41 ISCUs) | | | | | |
| Wind Speed Board | U-component Board | V-component Board | Temperature Board | Relative Humidity Board | Precipitation Board |
| 10% | 0% | 0% | 3% | 0% | 3% |

## IV. LITERATURE CITED

Barnes, S.L., 1964: A technique for maximizing details in numerical weather map analysis. J. Appl. Meteor., 3, 396-409.

Bonds, J.A., 1982: 1981 CCOPE Data Inventory: Bureau of Reclamation. Denver, CO., 451 pp.

Holman, L. and J. McInerney, 1982: 1981 CCOPE PROBE Mesonet Quality Control, Prepared for the Bureau of Reclamation, Contract No. 1-07-81-V0175, MT Dept. of Nat. Res. and Cons. , Helena, MT, 60 pp.

Knudsen, Gerhard M., Richard M. Moy, et al., 1981: State of Montana Activities in the High Plains Cooperative Program: 1975-1980, Final Report. Prepared for the Bureau of Reclamation, Contract No. 14-06-D-7577, MT Dept. of Nat. Res. and Cons., Helena, MT, 287 pp.

Politte, F.E. and T. Engel, 1982: Meso-network Users Manual, Bureau of Reclamation, Engineering and Research Center, Denver, CO, 45 pp.

APPENDIX A

MESONET RELATIVE HUMIDITY CALIBRATIONS

Figure A.1 RH Calibration Differences

Sensor S/N 809560 Site MOS

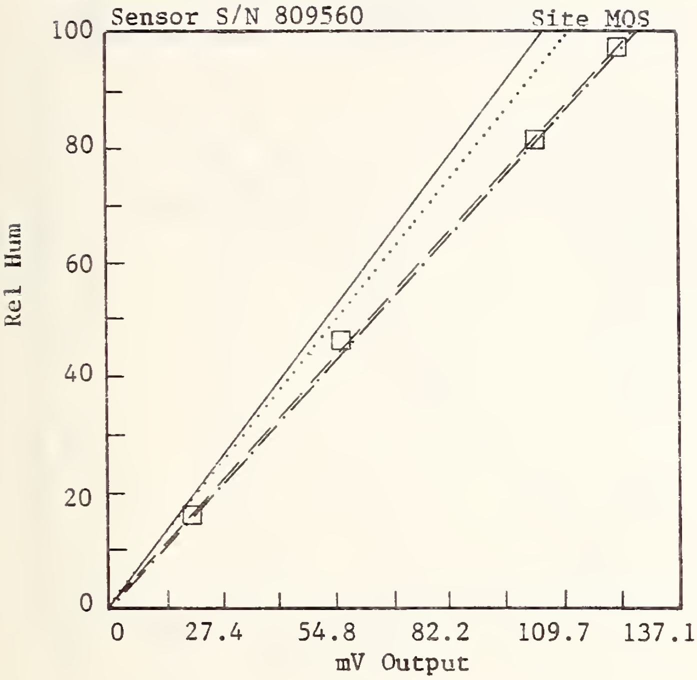



Figure A.2 RH Calibration Differences

Sensor S/N 809600 Site MOI

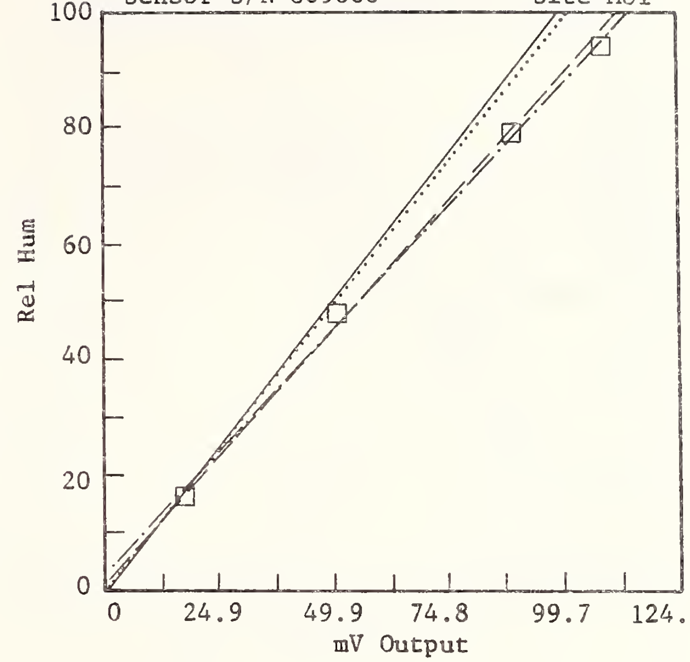



Figure A.3 RH Calibration Differences

Sensor S/N 809624 Site MOO

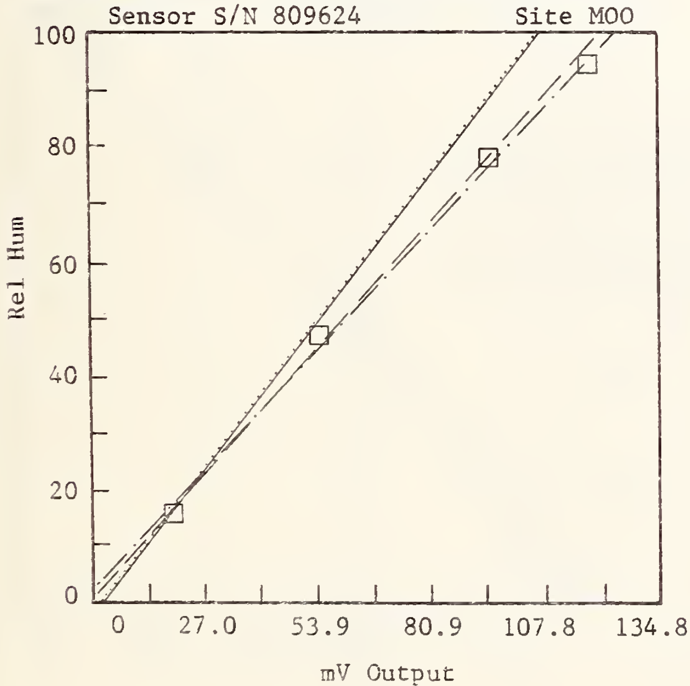
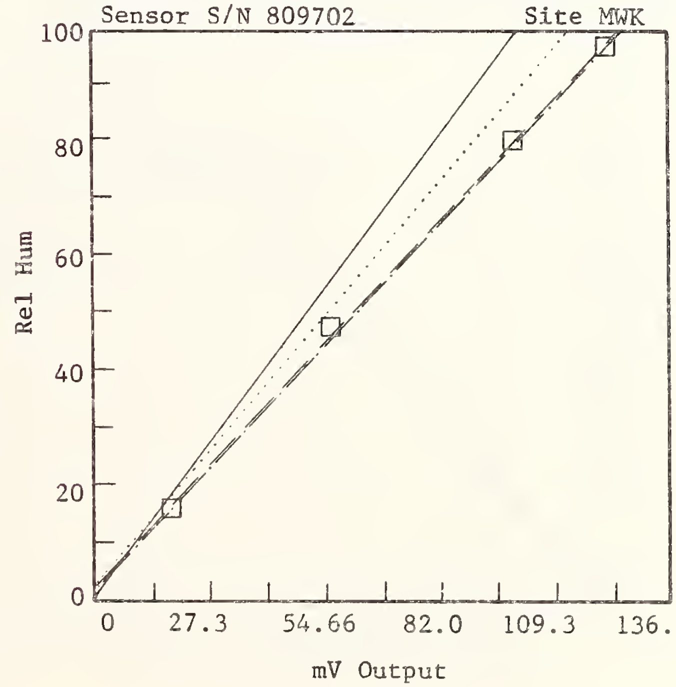



Figure A.4 RH Calibration Differences

Sensor S/N 809702 Site MWK




Preseason calibration line

Postseason calibration line (lower 3 pts)

Postseason calibration line (all 4 pts)

In situ calibration line

Postseason calibration check data points

Figure A.5 Non-Linear RH Calibrations

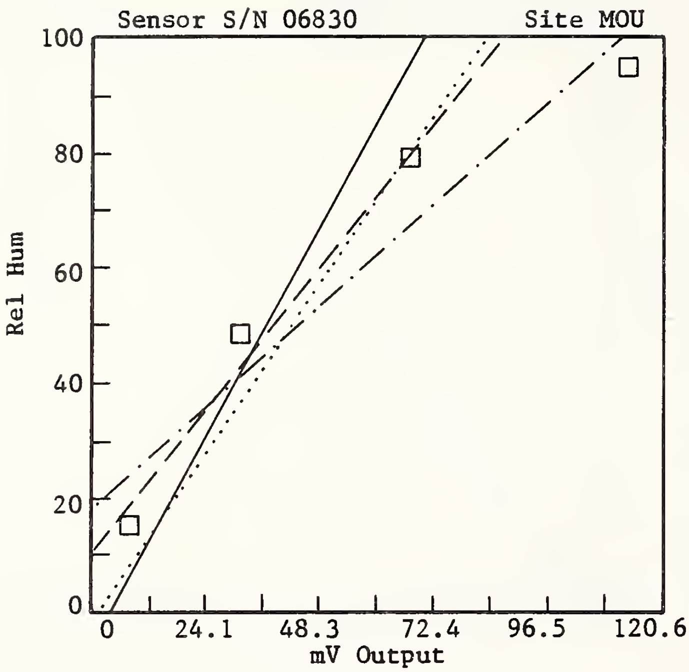



Figure A.6 Non-Linear RH Calibrations

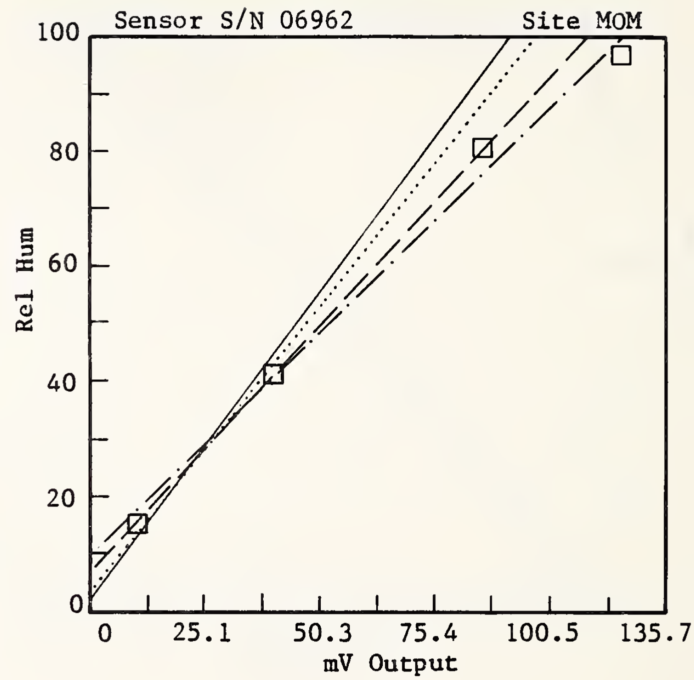



Figure A.7 Non-Linear RH Calibrations

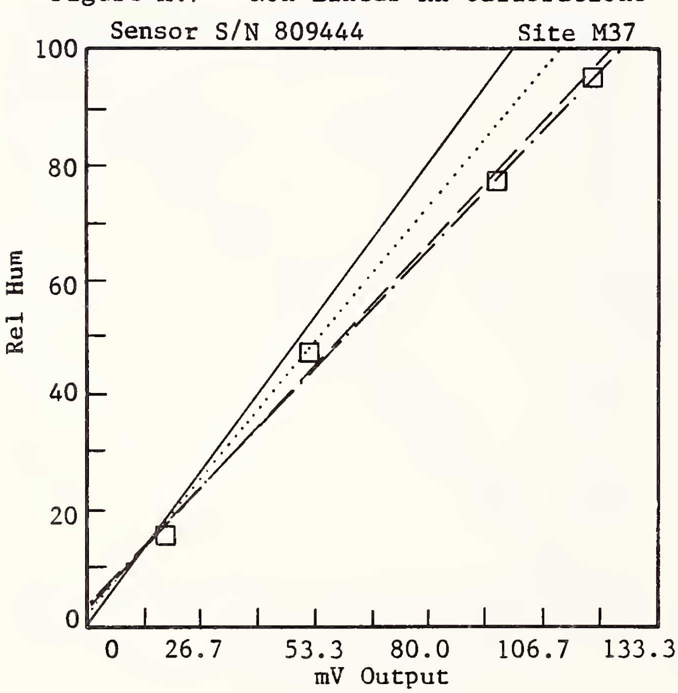
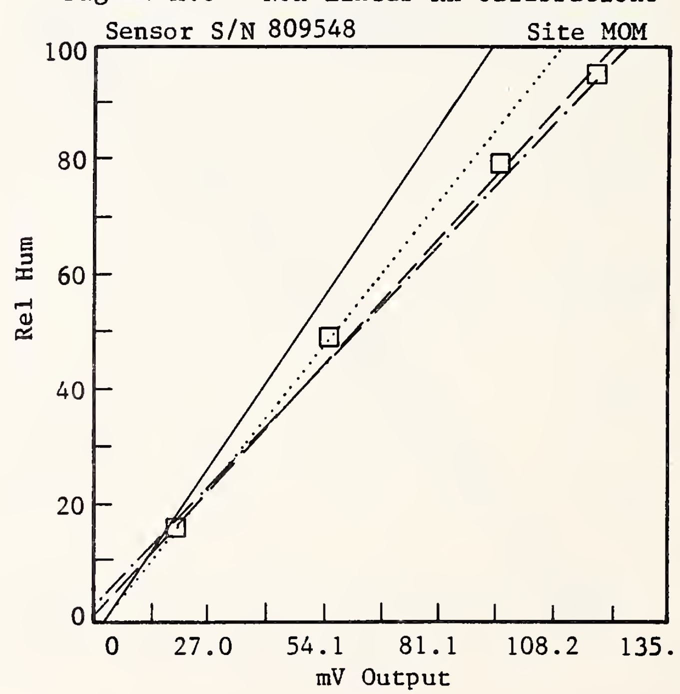



Figure A.8 Non-Linear RH Calibrations




Preseason calibration line

Postseason calibration line (lower 3 pts)

Postseason calibration line (all 4 pts)

In situ calibration line

□ Postseason calibration check data points

Figure A.9 Non-Linear RH Calibrations

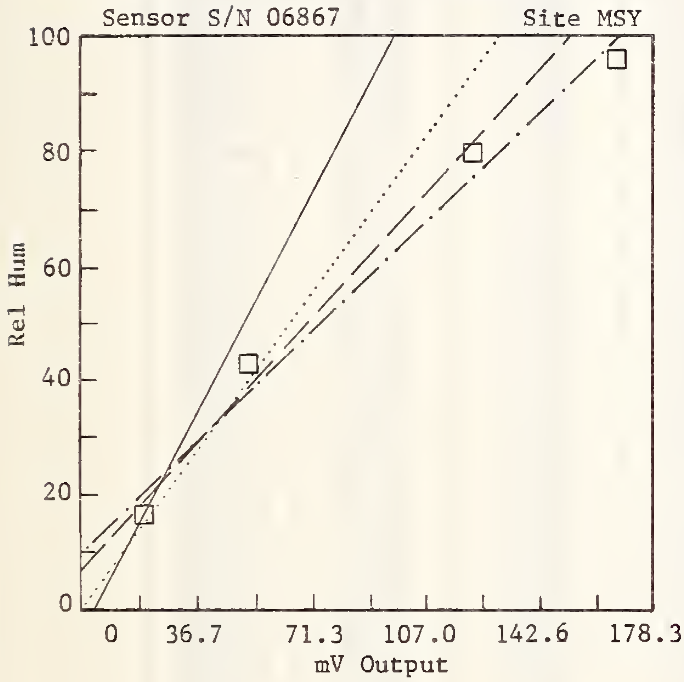
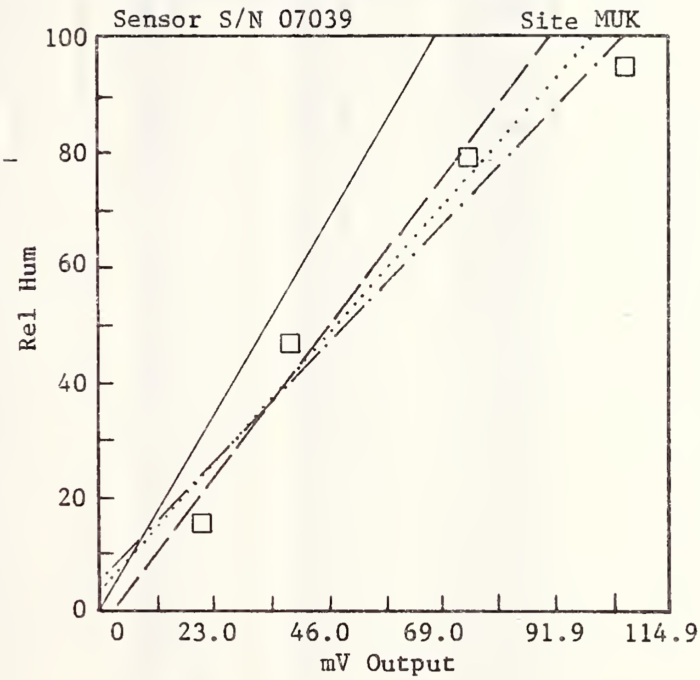



Figure A.10 Non-Linear RH Calibrations




Preseason calibration line
Postseason calibration line (lower 3 pts)
Postseason calibration line (all 4 pts)
In situ Calibration line
Postseason calibration check data points

Table A.1 Sensor Calibrations

| Sensor S/N | In situ Calibration | | Postseason Calibration | | Corrections | |
|---|---|---|---|---|---|---|
| | a In situ | b In situ | a Post | b Post | a Corr | b Corr |
| 00001 | 0.95 | 8.00 | 0.88 | 10.00 | 0.93 | 2.55 |
| 06748 | 0.81 | 2.00 | 0.73 | 4.29 | 0.90 | 2.49 |
| 06752 | 0.97 | 5.00 | 0.82 | 7.13 | 0.84 | 2.92 |
| 06830 | 1.23 | -2.00 | 1.04 | 10.34 | 0.85 | 12.03 |
| 06859 | 1.02 | 2.00 | 0.93 | 4.72 | 0.92 | 2.89 |
| 06867 | 0.76 | 0.00 | 0.61 | 6.99 | 0.80 | 6.99 |
| 06873 | 1.01 | 0.00 | 0.98 | -0.11 | 0.97 | -0.11 |
| 06877 | 0.87 | 2.00 | 0.90 | 0.49 | 1.04 | -1.58 |
| 06893 | 0.84 | 2.00 | 0.84 | 7.26 | 0.99 | 5.28 |
| 06904 | 0.78 | 4.00 | 0.72 | 4.41 | 0.92 | 0.72 |
| 06925 | 1.36 | -3.00 | 0.95 | 6.26 | 0.70 | 8.37 |
| 06930 | 1.10 | 0.00 | 1.03 | 1.26 | 0.93 | 1.26 |
| 06940 | 1.06 | -1.00 | 1.01 | 0.71 | 0.96 | 1.67 |
| 06945 | 1.10 | -1.00 | 1.07 | -0.07 | 0.98 | 0.91 |
| 06962 | 1.00 | 3.00 | 0.86 | 6.91 | 0.86 | 4.32 |
| 06973 | 0.84 | 5.00 | 0.81 | 4.55 | 0.97 | -0.31 |
| 06977 | 0.95 | 0.00 | 0.95 | 0.91 | 1.00 | 0.91 |
| 07008 | 0.99 | 0.00 | 1.00 | 0.98 | 1.01 | 0.98 |
| 07016 | 1.10 | -9.00 | 1.00 | -5.51 | 0.91 | 2.67 |
| 07039 | 0.97 | 4.00 | 1.14 | -3.04 | 1.18 | -7.75 |
| 07040 | 1.09 | -1.00 | 1.03 | 0.14 | 0.95 | 1.09 |
| 07043 | 1.15 | -2.00 | 1.05 | 0.83 | 0.91 | 2.66 |
| 07045 | 0.99 | 3.00 | 0.98 | 3.39 | 0.99 | 0.41 |
| 07057 | 0.90 | 1.00 | 0.87 | 3.01 | 0.96 | 2.05 |
| 07058 | 1.10 | 0.00 | 0.97 | 4.87 | 0.88 | 4.87 |
| 07077 | 1.06 | 1.00 | 1.04 | 1.58 | 0.98 | 0.60 |
| 07078 | 1.05 | -1.00 | 1.04 | -0.23 | 0.99 | 0.76 |
| 07079 | 1.07 | -1.00 | 0.99 | 6.75 | 0.93 | 7.68 |
| 07084 | 1.12 | -1.00 | 1.03 | 2.13 | 0.92 | 3.05 |
| 07088 | 1.05 | -1.00 | 0.95 | 2.33 | 0.90 | 3.23 |
| 07089 | 1.05 | -1.00 | 0.92 | 2.77 | 0.88 | 3.66 |
| 07090 | 0.98 | 1.00 | 0.99 | 2.02 | 1.00 | 1.02 |
| 07092 | 0.95 | 1.00 | 0.69 | 14.30 | 0.72 | 13.58 |
| 07094 | 0.89 | 8.00 | 0.84 | 8.10 | 0.94 | 0.61 |
| 07111 | 1.06 | -1.00 | 1.03 | -1.25 | 0.97 | -0.27 |
| 07126 | 1.14 | -4.00 | 1.08 | -0.72 | 0.95 | 3.09 |
| 07127 | 0.92 | 7.00 | 0.85 | 8.90 | 0.93 | 2.42 |
| 07132 | 1.15 | -2.00 | 1.00 | 3.12 | 0.87 | 4.87 |
| 07140 | 0.89 | 7.00 | 0.86 | 10.02 | 0.97 | 3.22 |
| 07154 | 0.93 | 3.00 | 0.84 | 6.05 | 0.90 | 3.34 |
| 804887 | 0.96 | 4.00 | 0.94 | 4.96 | 0.98 | 1.05 |
| 805140 | 1.13 | 0.00 | 1.01 | 4.33 | 0.89 | 4.33 |
| 805181 | 1.00 | 3.00 | 1.03 | 8.73 | 1.03 | 5.62 |
| 805212 | 0.89 | 5.00 | 0.91 | 5.67 | 1.02 | 0.57 |
| 805261 | 1.05 | 1.00 | 0.95 | 12.30 | 0.90 | 11.40 |
| 805318 | 0.83 | 2.00 | 0.84 | -0.62 | 1.01 | -2.64 |
| 805586 | 0.99 | 6.00 | 0.94 | 6.25 | 0.94 | 0.60 |
| 805618 | 0.89 | 1.00 | 0.82 | 0.01 | 0.92 | -0.91 |
| 805622 | 0.84 | -1.00 | 0.83 | -0.30 | 0.99 | 0.69 |
| 807734 | 0.90 | 0.00 | 0.81 | 2.12 | 0.90 | 2.12 |
| 808319 | 0.86 | 2.00 | 0.84 | 0.61 | 0.98 | -1.34 |
| 808875 | 0.91 | 2.00 | 0.86 | 1.63 | 0.94 | -0.26 |
| 809008 | 0.86 | 0.00 | 0.78 | 0.29 | 0.91 | 0.29 |
| 809285 | 0.91 | -3.00 | 0.82 | 2.35 | 0.90 | 5.05 |
| 809343 | 0.92 | 2.00 | 0.91 | -0.37 | 0.99 | -2.35 |
| 809378 | 0.88 | 0.00 | 0.82 | 1.22 | 0.94 | 1.22 |
| 809388 | 0.99 | -3.00 | 0.88 | 0.26 | 0.89 | 2.93 |
| 809395 | 0.95 | 1.00 | 0.92 | -0.06 | 0.97 | -1.03 |
| 809444 | 0.89 | 2.00 | 0.81 | 1.95 | 0.91 | 0.13 |
| 809446 | 0.90 | -1.00 | 0.81 | 2.01 | 0.90 | 2.90 |
| 809450 | 0.97 | 2.00 | 0.95 | 0.90 | 0.98 | -1.05 |
| 809453 | 0.93 | 0.00 | 0.90 | 1.81 | 0.96 | 1.81 |
| 809454 | 0.94 | 1.00 | 0.93 | 0.56 | 0.99 | -0.43 |

Table A.1 (continued)

| Sensor S/N | In situ Calibration | | Postseason Calibration | | Corrections | |
|---|---|---|---|---|---|---|
| | a In situ | b In situ | a Post | b Post | a Corr | b Corr |
| 809456 | 0.99 | -1.00 | 0.91 | 1.48 | 0.92 | 2.40 |
| 809459 | 1.05 | -2.00 | 0.95 | 0.46 | 0.91 | 2.27 |
| 809460 | 0.97 | 2.00 | 0.95 | 1.06 | 0.98 | -0.90 |
| 809461 | 0.91 | 2.00 | 0.89 | 0.33 | 0.97 | -1.61 |
| 809462 | 0.89 | 2.00 | 0.82 | 1.73 | 0.93 | -0.12 |
| 809463 | 0.87 | -1.00 | 0.83 | 0.76 | 0.95 | 1.71 |
| 809464 | 0.89 | -1.00 | 0.81 | -0.08 | 0.92 | 0.84 |
| 809468 | 0.93 | -1.00 | 0.89 | 1.68 | 0.95 | 2.63 |
| 809548 | 0.93 | -2.00 | 0.82 | 0.79 | 0.88 | 2.55 |
| 809550 | 0.93 | -2.00 | 0.85 | 1.38 | 0.91 | 3.20 |
| 809558 | 0.89 | 0.00 | 0.83 | 0.33 | 0.94 | 0.33 |
| 809560 | 0.89 | 1.00 | 0.78 | 0.91 | 0.88 | 0.03 |
| 809561 | 0.89 | -1.00 | 0.86 | 0.55 | 0.96 | 1.51 |
| 809566 | 0.89 | 2.00 | 0.85 | 1.33 | 0.95 | -0.57 |
| 809599 | 0.84 | 3.00 | 0.85 | 2.01 | 1.01 | -1.01 |
| 809600 | 0.97 | 1.00 | 0.88 | 1.06 | 0.91 | 0.15 |
| 809604 | 0.84 | -4.00 | 0.79 | 1.08 | 0.95 | 4.87 |
| 809617 | 0.83 | 2.00 | 0.82 | 0.85 | 0.98 | -1.12 |
| 809622 | 0.83 | 2.00 | 0.80 | 0.55 | 0.96 | -1.36 |
| 809624 | 0.96 | -2.00 | 0.82 | 0.90 | 0.86 | 2.62 |
| 809626 | 0.89 | -1.00 | 0.83 | 0.22 | 0.93 | 1.15 |
| 809632 | 0.77 | 2.00 | 0.77 | 0.00 | 0.99 | -1.99 |
| 809634 | 0.85 | -1.00 | 0.79 | 0.95 | 0.93 | 1.88 |
| 809644 | 0.78 | 3.00 | 0.74 | 1.96 | 0.95 | -0.89 |
| 809646 | 0.82 | 0.00 | 0.78 | 0.95 | 0.95 | 0.95 |
| 809647 | 0.77 | 3.00 | 0.75 | 1.56 | 0.98 | -1.37 |
| 809662 | 0.84 | 2.00 | 0.79 | 0.84 | 0.94 | -1.04 |
| 809690 | 0.80 | 0.00 | 0.73 | 3.01 | 0.92 | 3.01 |
| 809702 | 0.86 | 2.00 | 0.77 | 2.44 | 0.90 | 0.64 |
| 809708 | 0.83 | -1.00 | 0.76 | 1.68 | 0.92 | 2.59 |
| 809713 | 0.77 | 2.00 | 0.72 | 1.66 | 0.93 | -0.21 |
| 809714 | 0.83 | 0.00 | 0.78 | 1.75 | 0.94 | 1.75 |
| 809716 | 0.86 | 0.00 | 0.83 | -0.17 | 0.97 | -0.17 |

# APPENDIX B

# MESONET (ISCU) CALIBRATION TEST PROCEDURE

# MESONET (ISCU) CALIBRATION TEST PROCEDURE

Calibration Procedure

Date________________

## MOTHER BOARD

I. Test Equipment Required

The following items of test equipment or industry equivalents are required.

A. ETI Multifunction Test Set (MFTS)

B. Fluke Model 8050A Digital Voltmeter (DVM)

C. Hewlett Packard Model 5315A Frequency Counter

D. Dual Channel Oscilloscope

II. Initial Mother Board Calibration

1. Prior to beginning calibration, check mother board power supply voltage and record. Adjust and record voltages:

2. +12 Non-adjustable

3. -12 Non-adjustable

4. +5) Adjust R-10 for 5.010

5. -5)

6. To check operation of the ADK, inhibit. Connect DVM to pin 9 of any daughter board location. Verify a logic "1" level. Jumper +12 VDC from TB-1 pin 1 or TB-1 pin 6 using a 5K resistor to simulate input from DCP. The DVM should not show a logic "0" level. Record, press reset on mother board and DVM should return to logic "1" level.

7. To check operation of the reset. Connect DVM to pin 12 of any daughter board and observe a logic "0" level. Press the reset on the mother board and observe a logic "1" level while reset is held depressed.

Calibration Procedure

Date________________

WIND SPEED CONVERTER

I. Test Equipment Required

The following items of test equipment or industry equivalents are required:

A. Hewlett Packard Model 5315A Frequency Counter

B. Fluke Model 8050A Digital Voltmeter (DVM)

C. ETI Multifunction Test Set (MFTS)

II. Calibration

1. Connection A5-P2 pin 2 to ground.

2. Connect the frequency counter to TP-1 and verify no pulses are present.

3. With the digital voltmeter observe the analog voltages at TP-2 and TP-3, and adjust R-11 until the voltage at TP-2 and TP-3 are 0.000 ± .004 VDC.

4. Remove ground from A5-P2 pin 2 and connect the pulse output of the MFTS to pin 2. Set MFTS switches to "run" and "+12". The frequency at TP-1 should be 2735hz ± 10hz.

5. Adjust R-1 for -2.000 ± .008 VDC at TP-2 and +2.000 ± .008 VDC at TP-3.

Calibration Procedures

Date__________________

## U AND V INTEGRATORS

I. Test Equipment Required

The following items of test equipment or industry equivalents are required.

A. ETI Multifunction Test Set (MFTS)

B. Fluke Model 8050A Digital Voltmeter (DVM)

C. Hewlett Packard Model 5315A Frequency Counter

D. Dual Channel Scope

II. Calibration

A. Analog Section

1. Connect A6-P2 (U) or A7-P2 (V) pin 2 to ground.
2. Connect DVM to TP-2. Adjust R-1 for 0.000 ± .001 VDC.
3. Connect frequency counter to TP-3 and adjust R-9 for 13 ± 13hz.
4. Connect the analog output of the MFTS to pin 2 (remove ground) and adjust the MFTS for +2.000 ± .001 (TP-2 should read +2.000 ± .002 VDC).
5. Adjust R-8 for 13994 ± 13hz.
6. Switch the analog output of the MFTS to -2.000 ± .001 VDC.
7. Connect DVM to TP-1 and adjust R-3 for +2.000 ± .002 VDC.
8. Adjust MFTS for +2.000 ± .001 VDC output.

B. Digital Section

1. Switch all segments of SW-1 to off.
2. Connect a DVM to TP-5.
3. Connect the pulse output of the MFTS to TP-6. Set MFTS switches to count and +5.
4. Connect the analog output of the MFTS to A6-P2 (U) A7-P2 (V) pin 2 and adjust the output of the MFTS to +2.00 VDC.
5. Press reset on the mother board.
6. Adjust R-15 for +0.004 ± .002 VDC.
7. Press start on MFTS.
8. Adjust R-13 for +5.004 ± .002 VDC.
9. Press step on MFTS. Voltage at TP-5 should read value 0.004 ± 0.002 VDC.

PERFORM THE FOLLOWING OPERATIONAL CHECKS

1. Monitor the digital outputs; $2^9$ and $2^{10}$ with dual channel scope or DVM. For U outputs, P3-20 = $2^9$ P3-21 = $2^{10}$ and V outputs, P3-22 = $2^9$ P3-23 = $2^{10}$.
2. Monitor the analog output of U on P3-6 and V on P3-7.
3. Press reset on mother board. $2^9$ hi, $2^{10}$ low, analog 0 volts.
4. Press start on MFTS. $2^9$ hi, $2^{10}$ low, analog 5.0 volts.
5. Press step on MFTS. $2^9$ low, $2^{10}$ low, analog 0 volts.
6. Press start on MFTS. $2^9$ low, $2^{10}$ low, analog 5.0 volts.
7. Switch the analog output of the MFTS to -2.0 VDC.
8. Press reset on mother board. $2^9$ hi, $2^{10}$ low, analog 0.0 VDC.
9. Press start on MFTS. $2^9$ low, $2^{10}$ hi, analog 0.020 VDC.
10. Press step on MFTS. $2^9$ low, $2^{10}$ hi, analog 0.000 VDC.
11. Press start on MFTS. $2^9$ hi, $2^{10}$ hi, analog 0.020 VDC.
12. Press step on MFTS. $2^9$ hi, $2^{10}$ hi, analog 0.000 VDC.

    Disconnect all test equipment.

III. Set Integration Time

A. Select desired integration time and set corresponding segment of SW-1 to ON (only one segment to be in the ON position).

| SW-1 SEGMENT | INTEGRATION TIME MINUTES |
|---|---|
| 1 | 80.00 |
| 2 | 40.00 |
| 3 | 20.00 |
| 4 | 10.00 |
| 5 | 5.00 |
| 6 | 2.50 |
| 7 | 1.25 |

# PYRONOMETER INTEGRATOR

I. Test Equipment Required

A. E.T.I. MFTS

B. Fluke Model 8050A Digitial Voltmeter

C. H. P. Model 5315A Frequency Counter

D. Dual Channel Oscilloscope

II. Calibration

A. Analog Section

1. Connect A8-P2 pin 2 to pin 1 (gnd). Place A jumper on A8-P2 pin 3 to ground.
2. Connect DVM to U3 output pin #7.
3. Connect frequency counter to TP-1.
4. Adjust R-1 for 0.0 volts (record).
5. Adjust R-8 for 3 $\pm$ 3hz at TP-1.
6. Remove jumper from A8-P2 pin 3.
7. Connect MFTS analog output to A8-P2 pin 3. Adjust for 15.0 m.v.d.c. (DVM to input pin 3)
8. Adjust R-9 for 6987 $\pm$ 3hz on frequency counter.

B. Digital Section

1. Switch all segments of SW-1 to off.
2. Connect DVM to TP-3.
3. Connect pulse output of MFTS to TP-2. (Set MFTS for count and + 5.)
4. Press reset on mother board.
5. Adjust R-15 for .004 $\pm$ .002 VDC at TP-3.
6. Press start on MFTS.
7. Adjust R-13 for 5.004 $\pm$ .002 VDC at TP-3.
8. Press step on MFTS, TP-3 should read .004 $\pm$ .002 VDC.

PERFORM THE FOLLOWING OPERATIONAL CHECKS

1. Monitor the digital outputs $2^9$ and $2^{10}$ with dual channel scope or DVM. ($2^9$ is on P3-24 and $2^{10}$ is on P3-25.)
2. Monitor the analog out at P3-9.
3. Press reset on mother board, verify the following: $2^9$ hi, $2^{10}$ hi, analog 0.004.
4. Press start on MFTS. $2^9$ hi, $2^{10}$ hi, analog 5.004 $\pm$ .002 VDC.
5. Press step on MFTS. $2^9$ low, $2^{10}$ hi, analog 0.004 $\pm$ .002 VDC.
6. Press start on MFTS. $2^9$ low, $2^{10}$ hi, analog 5.004 $\pm$ .002 VDC.
7. Press step on MFTS. $2^9$ hi, $2^{10}$ low, analog 0.004 $\pm$ .002 VDC.
8. Press start on MFTS. $2^9$ hi, $2^{10}$ low, analog 5.004 $\pm$ .002 VDC.
9. Press step on MFTS. $2^9$ low, $2^{10}$ low, analog 0.004 $\pm$ .002 VDC.
10. Press start on MFTS. $2^9$ low, $2^{10}$ low, analog 5.004 $\pm$ .002 VDC. Disconnect all test equipment.

III. Set Integration Time

A. Select desired integration time and set corresponding segment of SW-1 to ON (only one segment to be in ON position).

| SW-1 SEGMENT | INTEGRATION TIME MINUTES |
|---|---|
| 1 | ---- |
| 2 | ---- |
| 3 | ---- |
| 4 | 1.25 |
| 5 | 2.50 |
| 6 | 5.00 |
| 7 | 10.00 |

Calibration Procedures

Date__________________

## TEMPERATURE INTEGRATOR

I. Test Equipment Required

The following items of test equipment or industry equivalents are required:

A. ETI Multifunction Test Set (MFTS)

B. Fluke Model 8050A Digital Voltmeter (DVM)

C. Hewlett Packard Model 5315A Frequency Counter

D. Dual Channel Oscilloscope

II. Calibration

A. Analog Section

1. Connect the analog output of the MFTS to A1-P2, pin 3.
2. Connect the DVM to A1-P2, pin 3.
3. Adjust analog output of MFTS for 3.078 VDC at pin 3.
4. Connect the DVM to U2 pin 6 (alternate, R-3) and adjust R-5 for 0.000 $\pm$ .001 VDC.
5. Connect the frequency counter to TP-1.
6. Adjust R-9 for 3 $\pm$ 3hz.
7. Connect the DVM to A1-P2 pin 3.
8. Adjust analog output of MFTS for 1.120 VDC.
9. Adjust R-8 for 6987 $\pm$ 3hz at TP-1.

B. Digital Section

1. Switch all segments of SW-1 to off.
2. Connect DVM to TP-3.
3. Connect pulse output of MFTS to TP-2. (Set MFTS for count and +5.)
4. Press reset on mother board.
5. Adjust R-15 for .004 $\pm$ .002 VDC at TP-3.
6. Press start on MFTS.
7. Adjust R-13 for 5.004 $\pm$ .002 VDC at TP-3.
8. Press step on MFTS, TP-3 should read .004 $\pm$ .002 VDC.

PERFORM THE FOLLOWING OPERATIONAL CHECKS

1. Monitor the digital output $2^9$ and $2^{10}$ with dual channel scope or DVM. ($2^9$ is on P3-11 and $2^{10}$ is on P3-10).
2. Monitor the analog out at P3-4.
3. Press reset on mother board, verify the following: $2^9$ hi, $2^{10}$ hi, analog 0.004.
4. Press start on MFTS. $2^9$ hi, $2^{10}$ hi, analog 5.004 $\pm$ .002 VDC.
5. Press step on MFTS. $2^9$ low, $2^{10}$ hi, analog 0.004 $\pm$ .002 VDC.
6. Press start on MFTS. $2^9$ low, $2^{10}$ hi, analog 5.004 $\pm$ .002 VDC.
7. Press step on MFTS. $2^9$ hi, $2^{10}$ low, analog 0.004 $\pm$ .002 VDC.
8. Press start on MFTS. $2^9$hi, $2^{10}$ low, analog 5.004 $\pm$ .002 VDC.
9. Press step on MFTS. $2^9$ low, $2^{10}$ low, analog 0.004 $\pm$ .002 VDC.
10. Press start on MFTS. $2^9$ low, $2^{10}$ low, analog 5.004 $\pm$ .002 VDC. Disconnect all test equipment.

III. Set Integration Time

A. Select desired integration time and set corresponding segment of SW-1 to ON (only one segment to be in ON position).

| SW-1 SEGMENT | INTEGRATION TIME MINUTES |
|---|---|
| 1 | ---- |
| 2 | ---- |
| 3 | ---- |
| 4 | 1.25 |
| 5 | 2.50 |
| 6 | 5.00 |
| 7 | 10.00 |

# CALIBRATION HUMIDITY

I. Test Equipment Required

The following items of test equipment or industry equivalents are required.

A. ETI Multifunction Test Set (MFTS)

B. Fluke Model 8050A Digital Voltmeter (DVM)

C. Hewlett Packard Model 5315A Frequency Counter

D. Dual Channel Oscilloscope

II. Calibration

A. Analog Section

1. Connect the DVM to A2-P2 pin 4.
2. Adjust R-17 for 3.600 $\pm$ .002 VDC.
3. Connect A2-P2 pin 2 to A2-P2 pin 3.
4. Connect DVM to U2 pin 6 (alternate R-3)
5. Adjust R-5 for 0.000 $\pm$ .001 VDC.
6. Connect frequency counter to TP-1.
7. Adjust R-9 for 3 $\pm$ 3hz.
8. Remove gnd. on pin 2-3.
9. Connect the analog out of the MFTS to A2-P2 pin 2 low output, A2-P2 pin 3 hi output (NOTE: Connecy MFTS ground to mother board ground for differential floating input to calibrate humidity analog section).
10. Connect the DVM to A2-P2 pins 2-3 adjust the MFTS output for + .200 $\pm$ .001 VDC.
11. Adjust R-8 for 6987 $\pm$ 3hz at TP-1.

B. Digital Section

1. Switch all segments of SW-1 to off.
2. Connect DVM to TP-3.
3. Connect pulse output of MFTS to TP-2. (Set MFTS for count and +5.)
4. Press reset on mother board.
5. Adjust R-15 for .004 $\pm$ .002 VDC at TP-3.
6. Press start on MFTS.
7. Adjust R-13 for 5.004 $\pm$ .002 VDC at TP-3.
8. Press step on MFTS, TP-3 should read .004 $\pm$ .002 VDC.

PERFORM THE FOLLOWING OPERATIONAL CHECKS

1. Monitor the digital outputs $2^9$ and $2^{10}$ with dual channel scope or DVM. ($2^9$ is on P3-13 and $2^{10}$ is on P3-12.)
2. Monitor the analog out at P3-5.
3. Press reset on mother board, verify the following: $2^9$ hi, $2^{10}$ hi, analog 0.004.
4. Press start on MFTS. $2^9$ hi, $2^{10}$ hi, analog 5.004 $\pm$ .002 VDC.
5. Press step on MFTS. $2^9$ low, $2^{10}$ hi, analog 0.004 $\pm$ .002 VDC.
6. Press start on MFTS. $2^9$ low, $2^{10}$ hi, analog 5.004 $\pm$ .002 VDC.
7. Press step on MFTS. $2^9$ hi, $2^{10}$ low, analog 0.004 $\pm$ .002 VDC.
8. Press start on MFTS. $2^9$ hi, $2^{10}$ low, analog 5.004 $\pm$ .002 VDC.
9. Press step on MFTS. $2^9$ low, $2^{10}$ low, analog 0.004 $\pm$ .002 VDC.
10. Press start on MFTS. $2^9$ low, $2^{10}$ low, analog 5.004 $\pm$ .002 VDC. Disconnect all test equipment.

III. Set Integration Time

A. Select desired integration time and set corresponding segment of SW-1 to ON (only one segment to be in ON position).

| SW-1 SEGMENT | INTEGRATION TIME MINUTES |
|---|---|
| 1 | ---- |
| 2 | ---- |
| 3 | ---- |
| 4 | 1.25 |
| 5 | 2.50 |
| 6 | 5.00 |
| 7 | 10.00 |

Calibration Procedures

Date_______________

## PRECIPITATION

I. Test Equipment Required

The following items of test equipment or industry equivalents are required:

A. ETI Multifunction Test Set (MFTS)

B. Fluke Model 8050A Digital Voltmeter (DVM)

C. Oscilloscope

II. Calibration

A. Digital Section

1. Turn power off.
2. Remove U-4 (4011). (Alternate: ground junction of R-2, U-4 pin 3,5,6)
3. Turn power on.
4. Connect pulse output of MFTS to TP-2. (Set for pulse operation.)
5. Connect DVM to TP-1
6. Press reset on mother board.
7. Adjust R-15 for 0 $\pm$ .001 VDC.
8. Press start on the MFTS three (3) times. (Wait 2 or 3 seconds between each push.)
9. Press step on the MFTS three (3) times.
10. Adjust R-9 for 3.750 $\pm$ .004 VDC.
11. Connect DVM to A3-P2 pin 6.
12. Press reset on mother board.
13. Press start on MFTS.
14. Adjust R-6 for 5.004 $\pm$ .002 VDC.

PERFORM THE FOLLOWING OPERATIONAL CHECKS

1. Monitor the digital outputs $2^9$ and $2^{10}$ with dual channel scope or DVM. ($2^9$ at J3 pin 15 and $2^{10}$ at J3 pin 14.)
2. Monitor analog output at J-3 pin 8.
3. Press reset on mother board. $2^9$ hi, $2^{10}$ hi, analog 0 VDC.
4. Press start on MFTS. $2^9$ hi, $2^{10}$ hi, analog 5 VDC.
5. Press step on MFTS. $2^9$ low, $2^{10}$ hi, analog 0 VDC.
6. Press start on MFTS. $2^9$ low, $2^{10}$ hi, analog 5 VDC.
7. Press step on MFTS. $2^9$ hi, $2^{10}$ low, analog 0 VDC.
8. Press start on MFTS. $2^9$ hi, $2^{10}$ low, analog 5 VDC.
9. Press step on MFTS. $2^9$ low, $2^{10}$ low, analog 0 VDC.
10. Press start on MFTS. $2^9$ low, $2^{10}$ low, analog 5 VDC.
    Replace U-4 or remove ground from R-2 and disconnect.
11. Connect MFTS analog (+) output to A3-P2 pin 2, set for "0" volts. Connect DVM to A3-P2 pin 6. Press reset.
12. Adjust MFTS output from 0 to +5.0 volts, the reading at pin 6 should cycle through 4 cycles from 0 to 5.0 volts. Indicate if OK on data sheet.
13. Disconnect all test equipment.

Calibration Procedures

Date_______________

# PRESSURE INTEGRATOR

I. Test Equipment Required

The following items of test equipment or industry equivalents are required:

A. ETI Multifunction Test Set (MFTS)

B. Fluke Model 8050A Digital Voltmeter (DVM)

C. Hewlett Packard Model 5315A Frequency Counter

D. Dual Channel Oscilloscope

E. Manometer

F. Setra Pressure Measurement System Model 270.

II. Calibration

A. Analog Section

1. Connect the pressure sensor outputs to A4-P2 pins 2 (green) and 3 (white).
2. Connect DVM to R-1 and adjust R-21 for 0 ± .001 VDC.
3. Connect the pressure sensor excitation to A4-P2 pins 4 (black) and 5 (red) (for S/N below 054 excitation connect to A4-P2 pins 1 and 4).
4. Connect manometer to pressure sensor.
5. Connect DVM to U-2 pin 6 (alternate R-3).
6. Connect frequency counter to TP-1.
7. Record Setra pressure reading.
8. Place a 16-inch $H_2O$ vacuum on sensor. (Set vacuum so that Setra reads -40.0mb below reading in step #7.)
9. Adjust R-5 for 0 ± .001.
10. Adjust R-9 for 3 ± 3hz.
11. Place a 16-inch $H_2O$ pressure on sensor. (Set manometer pressure for a Setra reading +40.0mb above reading in step #7.)
12. Adjust R-8 for 6987 ± 3hz.

    NOTE: Care must be taken when setting the manometer to insure accuracy of adjustments (Setra reading ± 40.0mb).
13. Remove pressure from manometer and set R-5 for a reading at TP-1 that corresponds to actual pressure indicated on Setra.

B. Digital Section

1. Switch all segments of SW-1 to off.
2. Connect DVM to TP-3.
3. Connect pulse output of MFTS to TP-2. (Set MFTS for count and +5.)
4. Press reset on mother board.
5. Adjust R-15 for .004 ± .002 VDC at TP-3.
6. Press start on MFTS.
7. Adjust R-13 for 5.004 ± .002 VDC at TP-3.
8. Press step on MFTS, TP-3 should read .004 ± .002 VDC.

PERFORM THE FOLLOWING OPERATIONAL CHECKS

1. Monitor the digital outputs $2^9$ and $2^{10}$ with dual channel scope or DVM. ($2^9$ is on P3-17 and $2^{10}$ is on P3-16.)
2. Monitor the analog out at P3-3.
3. Press reset on mother board, verify the following: $2^9$ hi, $2^{10}$ hi, analog 0.004.
4. Press start on MFTS. $2^9$ hi, $2^{10}$ hi, analog 5.004 ± .002 VDC.
5. Press step on MFTS. $2^9$ low, $2^{10}$ hi, analog 0.004 ± .002 VDC.
6. Press start on MFTS. $2^9$ low, $2^{10}$ hi, analog 5.004 ± .002 VDC.
7. Press step on MFTS. $2^9$ hi, $2^{10}$ low, analog 0.004 ± .002 VDC.
8. Press start on MFTS. $2^9$ hi, $2^{10}$ low, analog 5.004 ± .002 VDC.
9. Press step on MFTS. $2^9$ low, $2^{10}$ low, analog 0.004 ± .002 VDC.
10. Press start on MFTS. $2^9$ low, $2^{10}$ low, analog 5.004 ± .002 VDC.

    Disconnect all test equipment.

Figure III. Set Integration Time

A. Select desired integration time and set corresponding segment of SW-1 to ON (only one segment to be in ON position).

| SW-1 SEGMENT | INTEGRATION TIME MINUTES |
|---|---|
| 1 | ---- |
| 2 | ---- |
| 3 | ---- |
| 4 | 1.25 |
| 5 | 2.50 |
| 6 | 5.00 |
| 7 | 10.00 |

"ISCU" Calibration Form

15 Feb. 81

S/N: ____________________

DATE: ____________________

STA. ID: ____________________

TYPE TEST: ____________________

COMPONENTS REPLACED: ____________________

REMARKS: ____________________

____________________

**PYRONOMETER INTEGRATOR S/N** __________

(4) R-1 ______ vdc (5) TP-3 ______ vdc

(5) TP-1 ______ hz (7) TP-3 ______ vdc

(8) TP-1 ______ hz Operational Check

__________

Switch __________

**MOTHER BOARD S/N** __________

(1) ______ vdc

(2) +12 ______ vdc (3) -12 ______ vdc

(4) +5 ______ vdc (5) -5 ______ vdc

(6) Latch ______ (7) Reset ______

**TEMPERATURE INTEGRATOR S/N** __________

(4) R-3 ______ vdc (5) TP-3 ______ vdc

(6) TP-1 ______ hz (7) TP-3 ______ vdc

(9) TP-1 ______ hz Operational Check

__________

Switch __________

**WIND SPEED CONVERTER S/N** __________

(2) TP-1 ______ hz

(3) TP-2 ______ vdc TP-3 ______ vdc

(4) TP-1 ______ hz

(5) TP-2 ______ vdc TP-3 ______ vdc

**HUMIDITY INTEGRATOR S/N** __________

(2) Pin 4 ______ vdc (5) TP-3 ______ vdc

(5) R-3 ______ vdc (7) TP-3 ______ vdc

(7) TP-1 ______ hz Operational Check

(11) TP-1 ______ hz __________

Switch __________

**"U" INTEGRATOR S/N** __________

(2) TP-2 ______ vdc (6) TP-5 ______ vdc

(3) TP-3 ______ hz (8) TP-5 ______ vdc

(4) TP-2 ______ vdc Operational Check

(5) TP-3 ______ hz __________

(7) TP-1 ______ vdc Switch __________

**PRECIPITATION INTEGRATOR S/N** __________

(7) TP-1 ______ vdc

(10) TP-1 ______ vdc

(14) Pin 6 ______ vdc (12) __________

Operational Check __________

**"V" INTEGRATOR S/N** __________

(2) TP-2 ______ vdc (6) TP-5 ______ vdc

(3) TP-3 ______ hz (8) TP-5 ______ vdc

(4) TP-2 ______ vdc Operational Check

(5) TP-3 ______ hz __________

(7) TP-1 ______ vdc Switch __________

**PRESSURE INTEGRATOR S/N** __________

(8) R-3 ______ vdc (7) TP-3 ______ vdc

(9) TP-1 ______ hz Operational Check

(11) TP-1 ______ hz __________

(5) TP-3 ______ vdc Switch __________

(13) Setra ______ mb TP-1 ______ hz

# APPENDIX C

## MESONET DCP CALIBRATION TEST PROCEDURE

D.C.P. S/N: ____________ TEST DATE: ____________

M.B. S/N: ____________ INITIALS: ____________

SITE I.D.: ____________

Primary Ch. ____________

Emer. Ch. ____________

Prog. I.D. ____________

Report Time ____________

Prog. Par. ✓ OK ____________

Power Out

Forced Tx. (Dummy Load) ________ Watts Adjusted? Yes ___ No ___ Power Out Set To: ______ Watts

Record CH #146 = 401.9185 __________ MHz

Freq. CH #28 = 401.7415 __________ MHz

Out

Supply Voltage: A1 (CT.) Prog. Set

11.5 Volts __________

12.0 Volts __________

12.5 Volts __________

Analog Calibration:

| (Adjust) | Input Voltage (Pin #2) | A3 (CT.) Prog. Set |
|---|---|---|
| R93 | ________ | (0) ________ |
| (Fine) R91 (5.008) / (Coarse) R92 (5.012) | ________ | Lite (On) |
| | | (255) ________ |
| R93 (0) | ________ | (0) ________ |
| R93 (.010) (.011) | ________ | (1) ________ |
| | | (2) ________ |
| R93 (.028) (.030) | ________ | (254) To (255) ________ |
| R91 (4.989) (4.992) | ________ | |

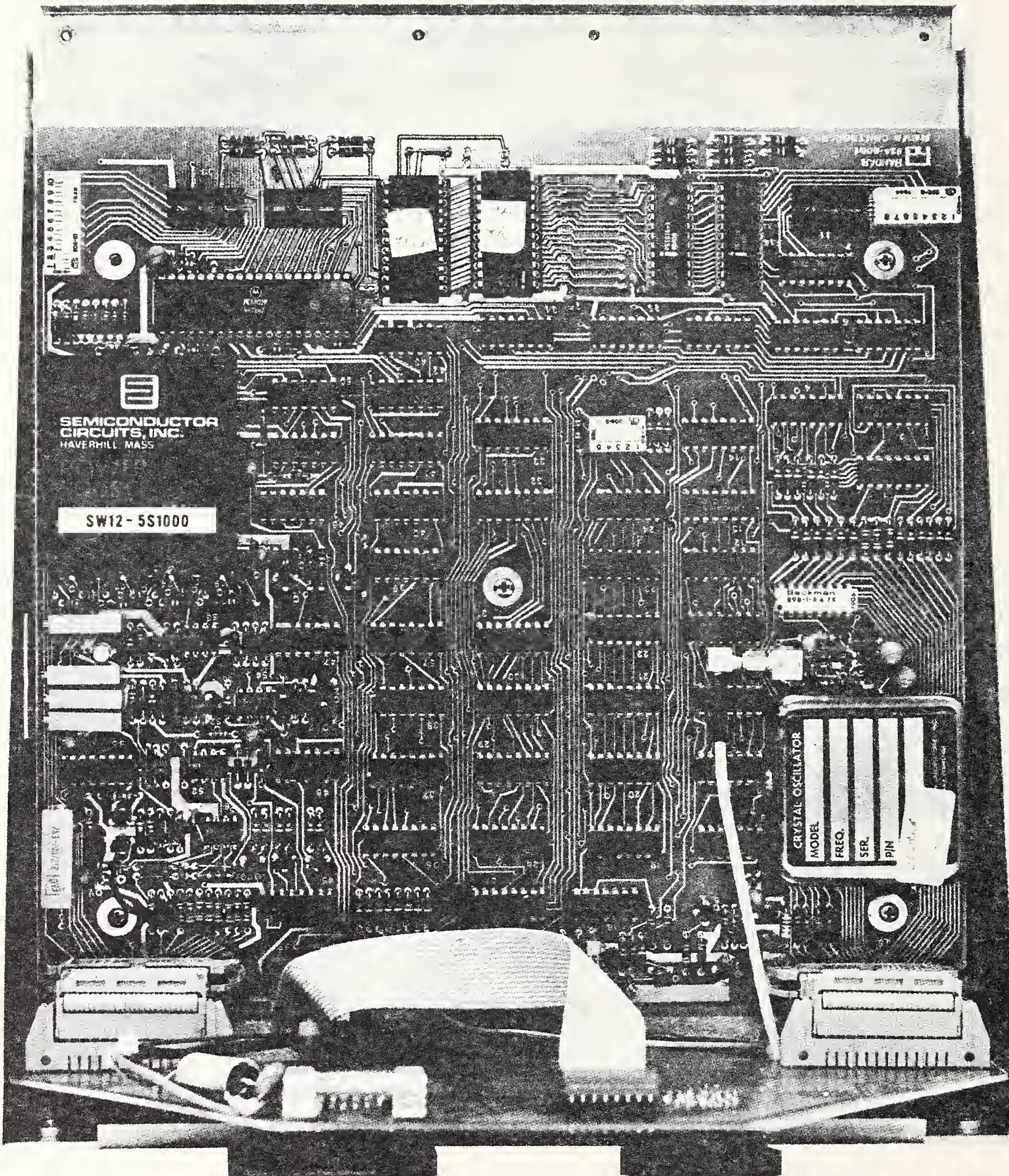
Time Prog. Up (HHMMSS) ________ Scan Delays ________ Tx Delay ________

Power Out (Actual) ________ Watts

Antenna # ________

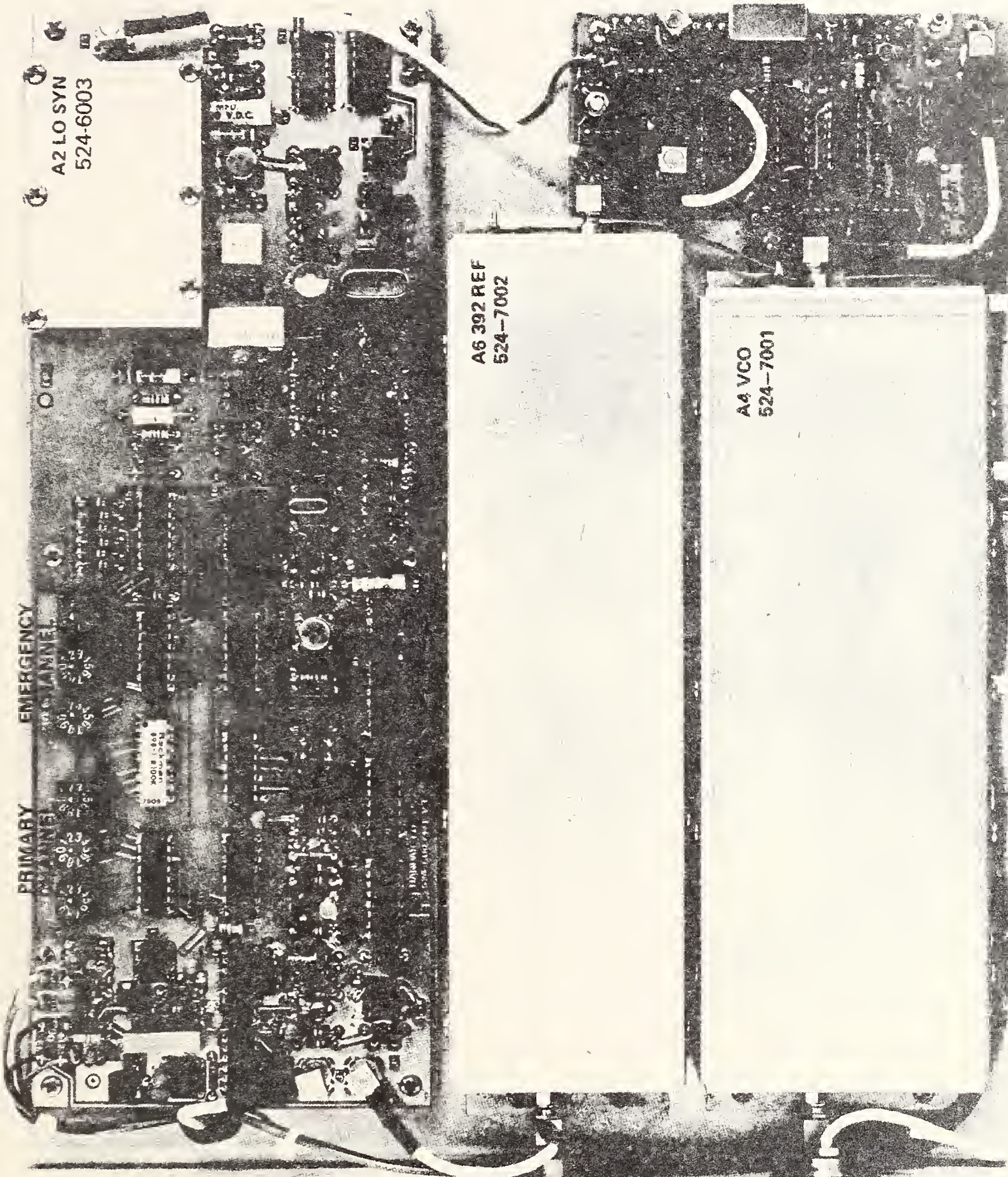
Goes/Computer Data Ck. Init.: ________ Date: ________

Time of Power-Down (HHMMSS) ________ Date: ________




524A Controller Layout

524 RF ASSEMBLY




524A RF Assembly Layout